Land Evaluation of some soils east of El-Fayoum Governorate, adjacent to Assuit desert road.

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ABSTRACT

The current study was carried out on the soils east of El Fayoum Governorate, adjacent to Cairo - Assiut desert road, Egypt. The study aimed to conduct a semi-detailed soil map suitable to conduct a soil capability and physical suitability evaluation using ILWIS GIS and the Automated Land Evaluation System (ALES).

Visual interpretation was first undertaken on an enhanced natural color composite Landsat TM image, overlaid on Digital Elevation Model (DEM) for the preparation of geo-pedological soil map using the 3D GIS analysis. The mapping units were strictly verified in the field where transect of sample areas including 29 soil profiles were selected to represent the different mapping units. The soil profiles were carefully described; the main physical and chemical characteristics of the different mapping units were determined and stored into ILWIS-GIS database. The soils were classified up to the sub group according to the protocol of the United States Department of Agriculture (USDA Soil Taxonomy, 2003). The main soils groups recorded in the studied area are; Petrogypsids, Haplocalcids, Haplosalids, Torriorthents and Haplotorrerts.

USDA soil capability classification was applied followed by physical land suitability evaluation using ILWIS-GIS to create the resulted maps. Eight land use types were selected; cotton, wheat, sorghum, sugar beet, onion, chamomile, olive and citrus. Five land qualities were considered based on the requirements of the selected LUTs, i.e., salinity & alkalinity, nutrient availability, moisture availability, oxygen availability and rooting conditions. The physical evaluation results indicated that the southern, middle and eastern parts of the studied area are classified as moderately suitable. Whereas, the northern parts are mostly classified as marginally or not suitable due to their salinity and cementation constraints.

Key words:

Land Evaluation, Land use types, East Fayoum soils, GIS, ILWIS and ALES Systems.

1. INTRODUCTION

El Fayoum Governorate occupies a circular depression in the Eocene Limestone plateau at the northern part of the western Desert of Egypt. It is Located at about 90 km to the south west of the Great Cairo. It is divided into six districts, namely; Tamia, Senours, Ibshaway, El Fayoum, Yousef El Sadic and Itsa. According to the population of 1997, the agricultural lands per capita is only 0.4 kirate. This hammers on the importance of exploring the desert lands around Fayoum Governorate to find out the suitable soils for agriculture and meet the urgent need to match land types and land uses in the most practicable and logical sustainable way. The full understanding of the geological, geomorphological and pedological, as well chemical and physical properties of these soils, is considered as the fundamental base for a successful reclamation plan in the area. Many private sector investments were paid in reclaiming soils around Fayoum depression, but sustainable agriculture are very rare. It is the duty of soil scientists to survey new lands and furnish the most suitable procedure for reclaiming and management of such soils.

1.1 Research objectives

The present study aimed to meet the following objectives;

a) To setup a suitable geographic soil database that can aid in the agricultural development east of El Fayoum Governorate, extended to Assiut desert road, Egypt.

b) To utilize information technology needed for digital soil database containing digitized soil maps stored with their attributes data and supported with chosen profiles point data.

c) To evaluate land resources in the study area and to create soil capability layer.

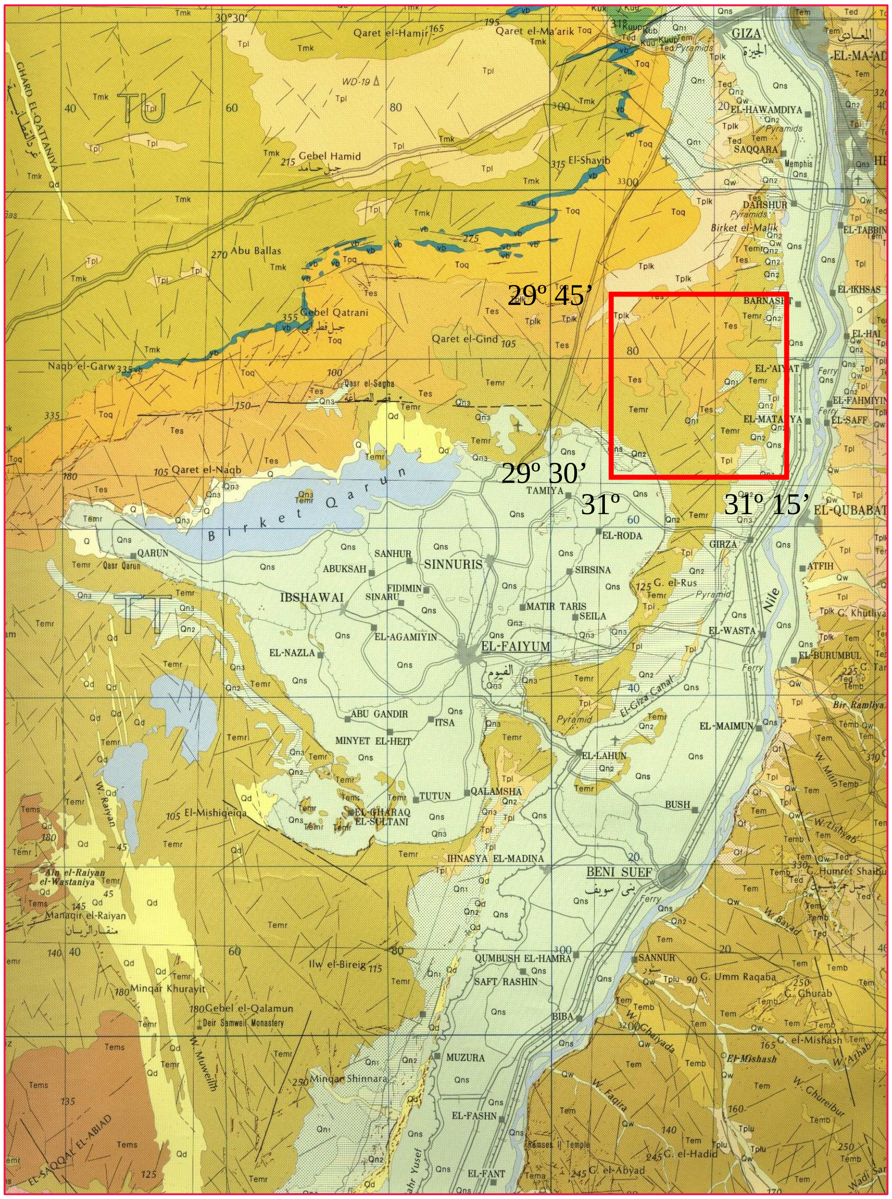
d) To evaluate the physical suitability to different crops which will help for planning the sustainable land use in the area.

1.2 General description of the studied area

The study area is located in the north east of Fayoum Depression, and pounded between latitudes 29 ^{o} 30’ and 29 ^{o} 45’ N and longitudes 31 ^{o} 00’ and 31^{o} 15’ E (Map 1). The area is bounded by Fayoum – Cairo desert road in the western side and Nile valley at El Saf District, Giza Governorate in the eastern side, while Cairo - Assiut desert road passes diagonally through the study area.

The area is characterized by a hot and dry summer with scanty winter rainfall and bright sunshine throughout the year. The average annual temperature is 22 ^{0}C, the average annual rainfall is 8 mm, while the average of daily evaporation is 6.75 mm/day.

According to the geological map of Fayoum 1: 500000, Conoco (1987), Gebel Qatrani Formation (Toq), belonging to Oligocene period covers the northern east part of the study area. It is formed mainly from sequence of continental to littoral marine clastics, siltstone, and reddish claystone. Going down west in the study area, Kom el-Shelul Formation (Tplk) appears. It is belonging to Pliocene period that composed mainly from sandstone beds , coquinal limestone and clays. Going down west in the study area, Qasr el-Sagha Formation (Tes) appears. It is composed mainly from Littorial marine to continental clastic sequence intercalated with silt and clay stones beds. Reaching beside the northern rim of El-Fayoum depression, Mokattam group-Wadi Rayan formation (Temr) appears which belonging to middle Eocene period. It is composed mainly from shallow marine limestone intercalated by shale and sandy shale. Beside the recent Nile valley deposits in the west, some isolated Quaternary Prenile deposits (Qn2) appear. Adjacent to the northern rim of Fayoum depression some Protonile deposits also appear.



Map 1. Location map of the study area displayed on the geological map.

2. MATERIALS AND METHODS

The work of this study had been conducted in 2004 as the following stages:

2.1 Satellite data interpretation and GIS application

2.2 Soil map generation.

2.3 Field work, Laboratory analysis and Coding soil database attributes.

2.4 Land capability assessment.

2.5 Land suitability assessment for different crops.

2.1 Satellite data interpretation and GIS application:

2.1.1 Geometric correction and registration:

The topographic map scale 1:50,000, (EGSA 1997) was scanned first with 250 dpi resolution and then imported into ILWIS GIS and geometrically corrected using polynomial order 1, Transverse Mercator projection and Helmert 1906 Spheroid. After that, it was re-projected into ETM projection system. The georeferenced topographic map had been used for projecting the TM image (June 1998) of the study area to the ETM system, by using image-to-image geometric correction module in ILWIS GIS, and used also for digitizing the contour, roads and Urban layers.

2.1.2 Satellite data processing and information extraction:

Stretching, contrast enhancement and convolution filtering were applied for radiometric and spatial enhancement. An enhanced false color composite of bands (7, 4, 1) of Landsat image is visually interpreted on the screen mainly to delineate the different land uses; namely, arable land, urban areas, bare soil, bare rocks, water bodies, and land cover. On the other hand, with help of overlaying the image on the 3D of the study area, the main landscape and the different topographic features important to produce the soil map of the study area are defined.

The following maps were digitized accurately to "ILWIS" GIS

- Contour lines and spot heights map, has been digitized from topographic maps 1:50000 scale with 1 meter intervals accuracy (EGSA, 1997).
- Digital Elevation Model (DTM), is made by interpolating the contour lines and spot heights using ILWIS map-calculation formulas and classifying it to slope classes. The contour map was imported to ARCVIEW GIS where 3D model is created.
- Slope map, has been made from the DTM map using ILWIS-GIS capabilities.
- Irrigation, drainage and road network maps digitized directly from the topographic map with scale 1: 50000 (superimposed all maps).

The geo-referenced topographic map, the geological map, the enhanced satellite image, and the 3D model of the study were used to generate the needed geopedologic soil map.

2.2 Soil map generation:

The geopedological approach (Zinck, 1989) is adapted to be applied on the satellite image interpretation. The enhanced natural colour composite is overlaid on 3D model, then visual interpretation is made to apply the geopedological approach and produce the soil map, Map 3 and Table 1.

2.3 Field work, Laboratory analysis and Coding soil database attributes.

A general reconnaissance survey is carried out first throughout the study area using intensive testing auger samples then, transect sampling method is applied to cross the different mapping units in the area. Three transects have been done where twenty three soil profiles were examined, Map 2. Detailed morphological description was recorded for each of the studied soil profiles, on the basis outlined by FAO (1977) and classified according to USDA (2003). The summary of the studied soil profiles description is shown on Table 2.

The collected soil samples (disturbed samples) are air dried; ground gently; and sieved through 2 mm sieve. Then, the main physical and chemical properties are determined, Gomaa (2004).

Attributes of soil mapping units and building up the soil database have been achieved by adding the values of different attributes after the analysis of representative soil modal profiles.

Re-interpretation analysis was done to finalize the interpreted boundaries using ILWIS-GIS after the establishment of the ground truth in the field. Consequently, the map legend was finalized and the physiographic units were finally translated in terms of soils, the finalized tabular legend was constructed with the help of the terminology instructions given by Zinck (1989).

The composition of each mapping unit was estimated with the help of the fieldwork combined with the image-interpretation.

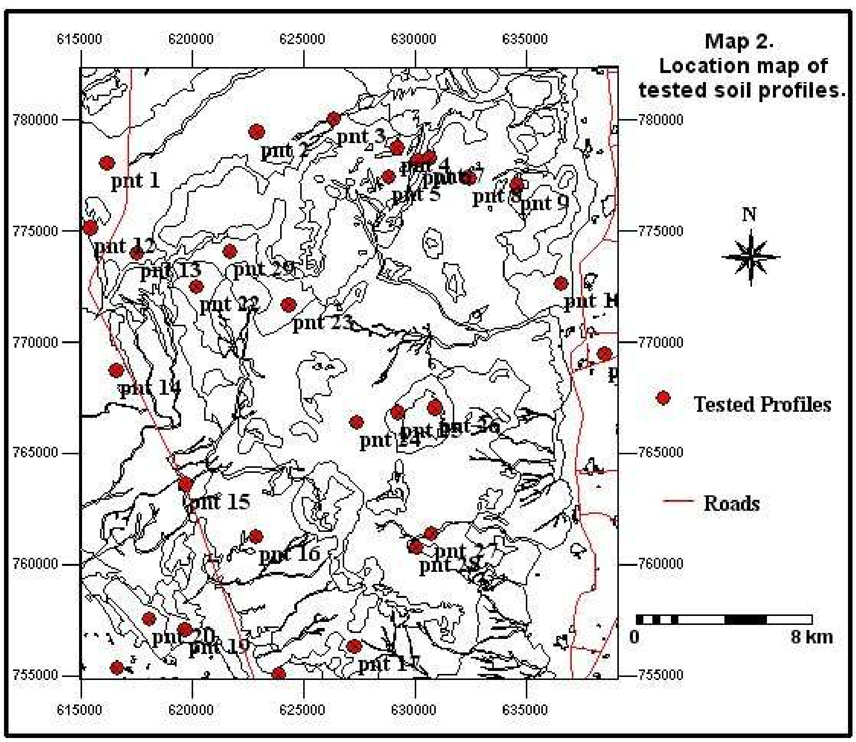
2.4 Land capability assessment.

California Storie index, Roy H. Bowman et al, (1973), is used to judge the soil grade for intensive agriculture. The results were displayed as maps using ILWIS GIS.

2.5 Land suitability assessment for different crops.

Physical land suitability evaluation is done according to FAO framework using the automated land evaluation system (ALES) software (Rossiter and Van Wambeke, 1997).

Figure 1, explains the methodological approach applied on this research work to execute and meet the present study objectives.



Map 2. Location map of the studied soil profiles.

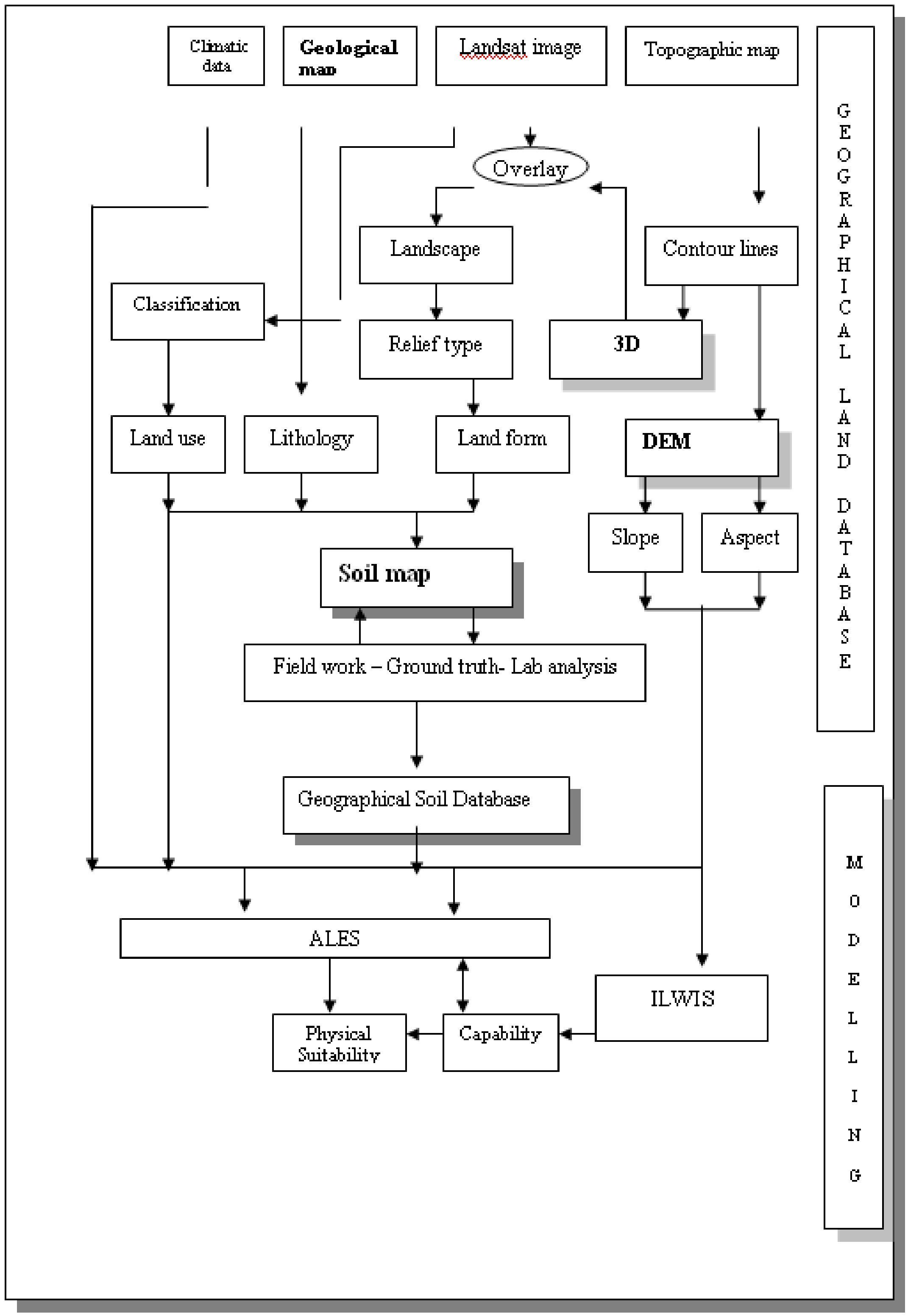


Figure 1. Methodological approach.

3. RESULTS AND DISCUSSIONS

3.1 The main morphological aspects of the studied soils

The main morphological aspects of the studied soil profiles are shown in Table 2. The soil color may reflect important clues about the constituents and about the oxidation-reduction status of the soils or their layers. As indicated in Table 2, the yellow color dominates in most layers of the dry samples. Whereas, the dark yellowish brown is found in layers of relatively high content of clay.

No clay migration evidence was observed and the sandy loam texture is the dominant soil texture in the area. Calcic formations are found in most of the studied soil profiles, especially in the subsurface layers, as lime nodules, lime concretions, shells and occasionally as soft powdery which fulfill the requirements of Calcic horizons especially in the piedmont and plain landscapes. Gypsum concretions, crystals and cementations are also common. It is noticed that Petrogypsic horizons is very common in the area especially in the relatively high elevation parts.

3.2 The main physical , chemical and soil fertility characteristics

The main physical , chemical and soil fertility characteristics are given in Tables 3,4,5,6 and 7. The results of the particle size distribution, Table 3, reveal variations in the texture classes whether among the profiles or along the entire depths of each profile.

Relatively high bulk density values, Table 4, were recorded and ranged between 1.14 and 1.74 g / cm3 in the soil samples. The coarse texture nature and the low organic matter contents, may contributed in the obtained relatively high bulk density values.

Relatively high values of soil hydraulic conductivity were obtained for the majority of the area reflecting the coarse soil texture nature. The maximum value 26.51 cm/hr recoded in profile 27 that having a loamy sand texture. The minimum values were 0.85 to 1.97 cm/hr, recorded in profile 11 that having a clayey texture. The average values of available water, Table 6, ranged from 6.12 to 26.7%. the minimum value recoded in a sandy loam texture with 39.78% total porosity, whereas the maximum value is recoded in a clayey texture with 55.9% total porosity.

Calcium carbonate content ranged between 1.29 to 32.57% with a general trend to increase in the profile bottoms reflecting the calcareous parent materials nature in the studied profile.

The area is characterized by low contents of organic matter that ranged between 0.05 -1.82 % in a good agreement with the prevailing arid conditions .

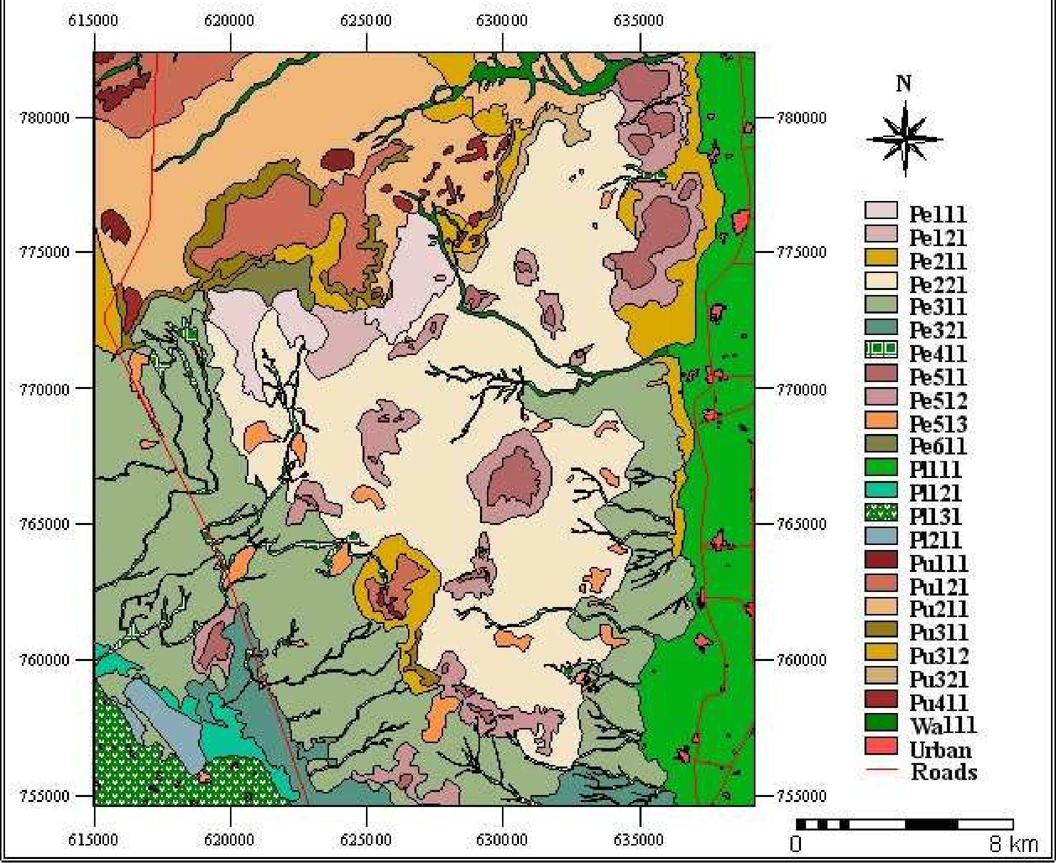
Free iron oxides is tested in some reddish samples and ranged from 0.57 to 7.79%. The occurrence of some iron segregations in Kom Oshim area is attributed to old intensive leaching process and old enrichment from El-Qatrani basic rocks, Shendi (1990).

Very wide variation in gypsum content are recorded among the studied soil samples and ranged between 1.36 to 18.82%. However, it is noticed that gypsic and petrogypsic horizons are common in the majority of the study area.

Most of the studied soil samples indicating slightly alkaline soil reaction ranging between 7.12 to 8.32.

Considerably varied salinity level are obtained. In some profiles salinity increases with depth reflecting the Eocene marine nature in the profile bottoms.

Map 3. Geopedological map of the study area.



The highest salinity value was 35.56 dS/m recorded in profile 22. Salic horizons were common in the piedmont high terrace Pe111 and to less extend in Pe121 mapping units. Associations of salic horizon were recorded also in the plain high terrace Pl121 mapping unit.

The Cation Exchange Capacity values ranged between 2.85 to 35.68 me /100g soil which affected mainly by the dominant coarse texture classes. Exchangeable sodium percentage values are relatively low and varies from 2.81 to 13.28. The occurrence of free calcium from gypsum and $CaCO_3$ may contribute in low ESP values prevailed.
The nitrogen, phosphorus and potassium status in Table 7, shows a relatively low fertility potential for the investigated areas.

Table 1. The geopedlogical map legend

Landscape	Relief	Lithology	Land Form	Map Symbol	Area Feddan	Modal Profile	Soil Classification
Plateau Pu	Mesa	Gypsiferous Siltstone and reddish claystone	Flat	Pu 111	722.16	x	Rockout crop
		Sandstone and marl	Flat	Pu 121	6374.93	x	Rockout crop
	Terrace	Sandstone and marl	Tread	Pu 211	18020.9	13	Calcic Petrogypsids 70% Typic Petrogypsids 15% Typic Torriorthents 15%
	Escarpment	Sandstone and marl	Escarpment	Pu 311	2737.41	x	Rockout crop
			Steep back slope	Pu 312	4694.22	6	Typic Torriorthents 75% Typic Petrogypsids 25%
		Marine deposits intercalated with marl	Back slope	Pu 321	716.73	7	Typic Torriorthents 70% Calcic Petrogypsids 15% Typic Petrogypsids 15%
	Hills	Marine deposits intercalated with marl	Isolated hillocks	Pu 411	656.3	4	Typic Petrogypsids 75% Calcic Petrogypsids 25%
Piedmont Pe	High terrace	Marine deposits intercalated with marl	Tread	Pe 111	3502.69	22	Calcic Haplosalids 75% Calcic petrogypsids 25%
		Gypsiferous Protonile deposits	Tread	Pe 121	1218.48	23	Calcic Petrogypsids 70% Gypsic Haplosalids 30%
	Low terrace	Shallow marine limestone, shale	Tread	Pe 211	3624.19	10	Calcic Petrogypsids 70% Typic Torrifluvents 30%
		Undifferentiated Pliocene deposits	Tread	Pe 221	35038.96	24	Lithic Haplocalcids 75% Typic Haplocalcids 25%
	Erosional Glacis	Undifferentiated Pliocene deposits	Inter-fluves tread	Pe 311	34651.92	14	Calcic Petogypsids 100%
		Undifferentiated, Protonile deposits	Inter-fluves tread	Pe 321	4133.07	18	Calcic Petogypsids 100%
	Dry valleys	Alluvial, undifferentiated	Swales	Pe 411	3601.78	15	Typic Haplocalcids 70% Typic Torrifluvents 30%
	Hills	Shallow marine limestone, shale	Summit	Pe 511	3338.19	26	Calcic Petogypsids 100%
		Marine deposits intercalated with marl	Back slope	Pe 512	8336.84	25	Calcic Petogypsids 100%
		Marine deposits intercalated with marl	Slope facet complex	Pe 513	2193.5	28	Calcic Petogypsids 75% Typic Haplocalcids 25%
	Fans	Alluvial, colluvial, residual	Apical-frontal complex	Pe 610	830.47	29	Calcic Petogypsids 75% Typic Haplocalcids 25%
Plain Pl	High terrace	Alluvial	Tread	Pl 111	16436.07	11	Typic Haplotorrerts 75% Vertic Torrifluvents 25%
		Alluvial, colluvial, residual	Tread	Pl 121	1435.73	19	Typic Haplocalcids 70% Gypsic Haplosalids 30%
		Alluvial, residual	Tread	Pl 131	3451.86	21	Typic Haplocalcids 70% Typic Calcigypsids 30%
	Basin	Alluvial, colluvial, residual	Basin complex	Pl 211	1129.35	20	Typic Haplocalcids 70% Typic Calcigypsids 15% Typic Calcitorrerts 15%
Wadi Wa	Dry valley	Alluvial, residual	Swales	Wa 111	2222.4	3	Calcic Petogypsids 75% Typic Haplocalcids 15% Typic Torrifluvents 10%

Table 2. The main morphological aspects of the studied profiles.

Mapping unit symbol	Profile No.	Horizon	Depth (cm)	Soil color			Texture	Consist.	Soil structure			Horizon boundary	Calcic formations				Iron oxides			Stoniness		
				Hue	Dry	Moist			Grade	Size	Type		Effer.	Feat.	Quan.	Size	Feat.	Quan.	Size	Feat.	Quan.	Size
Pu211	1	C_1	0-5	10YR	6/4	5/4	sl	sh	1	f	mas	--	+	-	-	-	-	-	-	g	c	c
		C_2	5-40		7/6	6/4	s	lo	1	-	sg	cw	+	-	-	-	ba	m	m	r	f	s
		C3	40-60		6/4	5/4	s	lo	1	-	sg	d	++	lc	m	s	sp	f	m	g	c	s
		C_4	60-90	7.5YR	6/6	5/6	sl	sh	1	f	mas	gw	++	lc	m	m	ba	m	m	-	-	-
	2	C_1	0-10	10YR	6/7	6/6	sl	sh	2	f	sbk	--	++	lc	m	m	-	-	-	g	m	m
		C_2	10-20		7/6	6/6	sl	sh	1	f	mas	d	+	-	-	-	vi	m	c	g	m	s
		C3	20-50		7/6	6/6	sl	sh	1	f	mas	d	++	lcg	m	f	vi	m	c	g	f	s
		C_4	> 50		7/8	6/8	sl	sh	1	m	sbk	d	+	lcg	m	m	-	-	-	-	-	-
	5	C1	0-10	10YR	7/6	6/6	l	h	2	m	sbk	--	++	ln	m	s				g	m	s
		C2	10-20		7/6	6/6	sil	h	2	m	sbk	gw	++	lc	m	s						
		C3	20-35		7/6	6/6	sl	sh	1	f	mas	d	+++	lc	c	m						
		C_4	35-70		7/6	6/8	sl	sh	2	f	mas	d	+++	lcg	c	m						
		C_5	> 70		7/6	6/8	sl	sh	1	f	mas	d	+++	lcg	c	m						
	13*	C_1	0-15	7.5YR	6/6	5/4	sl	sh	1	f	mas	--	+	-	-	-				g	m	c
		C_2	15-55		6/6	5/6	sl	sh	1	f	mas	d	++	ln	f	s						
		C3	55-90	10YR	6/8	6/4	sl	sh	1	m	mas	d	+++	lcg	c	m	pa	m	m			
		C_4	> 90		6/8	6/4	l	h	2	M	sbk	gw	+	lcg	c	m	ba	m	m			
	12	C1	0-20	7.5YR	6/6	5/4	l	h	2	F	sbk	--	++	ln	f	s				g	m	c
		C_2	20-50	10YR	7/6	6/6	ls	sh	1	-	sg	gw	++	lcg	m	m	sp	f	m			

Texture	***Structure***			***Consistence***	***Calcic formations***		***Boundary***	***Mottling***		***Stones***
cl = Clay loam sl = Sandy loam ls = Loamy sand s = Sand	Grade 1 = Weak 2 = Moderate 3 = Strong	Size f = Fine m = Medium c = Coarse	Type mas = Massive sbk=Subangular blocky abk = Angular blocky	sh =Slightly hard h = Hard vh = Very hard l = loose	Feature 1n = Lime nodules 1c=Lime concretions sh = Shells g = Gypsum	Quantity f = Few m = Moderate c = Common	d = Diffuse gs=Gradual smooth gw=Gradual wavy cw = Clear wavy	Feature sp = Spots pa= patches ba = band vi = Veins	***Size*** s = Small m= Medium c = Coarse	Feature g = Gravel r = Rock fragment

Table 2. Cont.

Mapping unit symbol	Profile No.	Horizon	Depth (cm)	Soil color			Texture	Consist.	Soil structure			Horizon boundary	Calcic formations				Iron oxides			Stoniness		
				Hue	Dry	Moist			Grade	Size	Type		Effer.	Feat.	Quan.	Size	Feat.	Quan.	Size	Feat.	Quan.	Size
Pu312	6*	C1	0-30	1OYR	8/4	6/4	sl	sh	2	f	Sbk	-	++	lcg	m	m						
Pu321	7*	C1	0-30	7.5YR	6/6	5/4	l	h	2	f	spk	--	++	lcg	c	m	pa	m	m	--	--	--
Pu411	4*	C1	0-10	1OYR	7/6	6/6	l	sh	2	m	sbk	--	+	-	-	-	-	-	-	g	m	c
		C_2	10-30	5YR	7/4	7/6	cl	h	2	m	sbk	cw	++	lcg	c	c	pa	m	c	-	-	-
		C_3	> 30	1OYR	7/6	6/6	cl	h	2	m	sbk	d	++	lcg	c	c	-	-	-	-	-	-
Pe111	22*	C1	0-20	7.5 YR	6/6	5/4	l	h	2	f	spk	--	++	lcg	c	m	pa	m	m	--	--	--
		C2	20-50	10 YR	7/6	6/6	ls	sh	1	--	sg	gw	++	in	f	s	--	--	--	g	m	c
Pe121	23*	C1	0-10	10YR	7/6	6/6	l	h	2	m	spk	--	++	in	m	s				g	m	s
		C2	10-20		7/6	6/6	sil	h	2	m	spk	gw	++	ic	m	s						
		C3	20-35		7/6	6/6	sl	sh	1	f	mas	d	+++	ic	c	m						
		C4	35-70		7/6	6/8	sl	sh	2	f	mas	d	+++	icg	c	m						
		C5	70-100		7/6	6/8	sl	sh	1	f	mas	d	+++	icg	c	m						
Pe211	9	Ap	0-30	1OYR	6/6	5/6	cl	h	2	m	sbk	--	+	-	-	-						
		C_3	30-100	7.5YR	5/4	6/6	l	h	2	m	sbk	gs	+	-	-	-	pa	c	m			
	10*	C1	0-10	1OYR	6/6	5/4	sl	sh	2	m	mas	--	+	-	-	-	pa	m	m	g	m	c
		C2	> 10	5YR	6/8	5/8	scl	h	2	m	sbk	cw	++	lcg	m	m	ba	m	m			
Pe221	8	C_3	0-5	1OYR	7/6	6/6	l	h	2	f	sbk	--	+++	lcg	c	m				g	m	s
		C2	5-15		7/6	6/6	sl	sh	1	f	mas	cw	++	ln	m	m						
		C_3	15-30		7/6	6/6	sl	sh	1	f	mas	d	+	-	-	-	pa	m	s	g	m	s
	24*	C_1	0-5	1OYR	8/4	7/4	sl	sh	1	f	mas	--	++	ln	m	m						
		C_2	5-25		7/6	6/4	sl	sh	1	f	mas	d	+	-	-	-	ba	c	m			
		C_3	25-45	5YR	5/8	4/8	sil	h	2	m	sbk	cw	+++	lc	c	m	ba	c	m			
Pe311	14*	C_1	0-20	1OYR	6/6	5/8	ls	sh	1	-	sg	--	++	ln	m	m						
		C_2	20-70		6/4	5/6	ls	sh	1	-	Sg	D	++	lcg	f	s	pa	m	m			
		C3	> 70		5/4	4/4	cl	h	2	m	sbk	gw	++	lcg	c	m	ba	m	m			
	16	C_3	0-5	1OYR	8/4	7/4	cl	h	2	m	sbk	--	+++	ln	c	m						
		C2	5-20		8/4	7/6	cl	h	2	m	sbk	D	+++	lcg	c	c	pa	m	m			
	17	Ap	0-5	1OYR	6/6	5/8	l	h	2	m	sbk	--	++	ln	f	s						
		C_2	5-15		6/6	5/6	cl	h	2	m	sbk	gw	++	lcg	m	m	pa	m	m			
		C2	> 15	7.5YR	6/6	5/6	cl	h	2	m	sbk	d	+++	lc	c	c						

Table 2. Cont.

Mapping unit symbol	Profile No.	Horizon	Depth (cm)	Soil color			Texture	Consist.	Soil structure			Horizon boundary	Calcic formations				Iron oxides			Stoniness		
				Hue	Dry	Moist			Grade	Size	Type		Effer.	Feat.	Quan.	Size	Feat.	Quan.	Size	Feat.	Quan.	Size
Pe321	18*	C_1	0-5	1OYR	7/6	6/6	sl	sh	1	m	mas	--	++	ln	m	s				g	m	c
		C2	5-30		7/6	6/4	ls	sh	1	-	sg	gw	++	lcg	m	m	sp	f	m	-	-	-
		C3	30-50		7/6	7/8	sl	sh	1	f	mas	gs	++	lcg	m	m	pa	m	m	g	m	c
		C4	50-90		7/6	7/8	scl	h	2	m	sbk	cw	+++	lcg	c	c	ba	m	m	g	m	C
Pe411	15*	C1	0-20	1OYR	7/6	6/6	sl	sh	1	f	mas	--	+	-	-	-				g	f	m
		C_2	20-35		7/6	6/6	ls	sh	1	-	sg	gs	++	1n	f	s				g	f	s
		C_3	35-100		7/6	6/6	sl	sh	1	m	mas	gw	+	-	-	-				g	m	s
	27	Ap	0-10	1OYR	7/6	6/6	ls	sh	1	-	sg	--	+	-	-	-				g	f	m
		C1	10-30		6/6	5/8	ls	sh	1	-	sg	d	+	-	-	-						
		C2	30-65		6/6	5/6	sl	sh	1	f	mas	gs	++	ln	m	f						
		C_3	> 65		7/6	6/6	s	lo	1	-	sg	cw	++	lc	m	f				g	m	s
Pe511	26*	C1	0-20	1OYR	7/6	6/6	cl	vh	2	m	sbk	--	++	lcg	m	f				g	c	c
		C_2	> 20		8/4	7/4	sl	sh	1	f	mas	cw	+	lcg	c	m						
Pe512	25*	C1	0-20	10YR	7/6	6/6	sl	vh	2	m	spk	--	++	icg	m	f				g	c	c
		C2	20-40		8/4	7/4	sl	sh	1	f	mas	cw	+	icg	c	m						
Pe513	28*	C1	0-20	10YR	7/6	6/6	cl	vh	2	m	spk	--	++	icg	m	f				g	c	c
		C2	20-50		8/4	7/4	sl	sh	1	f	mas	cw	+	icg	c	m						
Pe611	29*	C1	0-20	10YR	7/6	6/6	cl	vh	2	m	spk	--	++	icg	m	f				g	c	c
		C2	20-50		8/4	7/4	sl	sh	1	f	mas	cw	+	icg	c	m						
Pl111	11*	Ap	0-30	10YR	4/4	4/2	c	h	2	m	sbk	--	+	-	-	-						
		C_{1ss}	30-60		4/4	4/2	c	vh	3	c	abk	d	+	-	-	-						
		C_2ss	60-120		4/4	4/2	c	vh	3	c	abk	d	+	-	-	-						
Pl121	19*	C1	0-20	10YR	7/6	6/6	sl	sh	1	f	mas	--	+							g	f	m
		C2	20-35		7/6	6/6	ls	sh	1	--	sg	gs	++	in	f	s				g	f	s
		C3	35-100		7/6	6/6	sl	sh	1	m	mas	gw	+									
Pl131	21*	Ap	0-25		7/6	6/6	cl	h	2	m	sbk	--	++	ln	f	s						
		C_2	25-50		6/6	7/4	scl	h	2	m	sbk	gw	+++	lcg	c	c	sp	f	s			
Pl211	20*	AP	0-25		7/6	6/6	cl	h	2	m	spk	--	++	in	f	s						
		C2	25-50		6/6	7/4	scl	h	2	m	spk	gw	+++	icg	c	c	sp	f	s			
Wa111	3*	C1	0-15	10YR	7/6	6/6	ls	sh	1	-	sg	--	++	1n	m	m				g	f	s
		C_2	15-35		7/6	6/6	sl	sh	1	m	mas	gs	+	lc	f	s				g	f	s
		C3	35-70		8/6	7/6	sl	sh	1	f	mas	d	+	lcg	c	m	sp	f	s			
		C_4	> 70		6/7	6/6	sl	sh	1	f	mas	d	+	lcg	c	c						

Table 3. Particle size distribution of the studied area

Mapping unit symbol	Profile No.	Depth (cm)	Gravel content %	Particle size distribution %				Textural grade
				Coarse sand	Fine sand	Silt	Clay	
Pu211	1	0-5	47.05	17.3	55.1	15.2	12.4	Very Gravelly Sandy loam
		5-40	7.85	23.6	73.4	6.8	5.2	Sand
		40-60	31.47	65.3	24.2	6.5	4.0	Gravelly Sand
		60-90	--	9.7	59.6	19.1	11.6	Sandy loam
	2	0-10	16.00	26.9	37.2	18.5	17.4	Gravelly Sandy loam
		10-20	15.56	27.6	48.4	16.2	7.8	Gravelly Sandy loam
		20-50	9.69	16.8	54.3	12.5	16.4	Sandy loam
		> 50	--	25.4	32.6	23.3	18.7	Sandy loam
	5	0-10	15.38	2.4	44.8	40.7	12.1	Gravelly Loam
		10-20	--	2.1	33.4	56.4	9.1	Silty loam
		20-35	--	25.5	45.3	22.8	6.4	Sandy loam
		35-70	--	21.4	57.6	9.9	11.1	Sandy loam
		> 70	--	18.7	43.5	25.2	12.6	Sandy loam
	13*	0-15	24.11	14.1	61.5	16.4	8.0	Gravelly Sandy loam
		15-55	--	25.7	41.1	21.5	11.7	Sandy loam
		55-90	--	19.8	38.4	27.6	14.2	Sandy loam
		> 90	--	5.1	43.6	33.8	17.5	Loam
	12	0-20	11.75	7.9	40.3	29.0	22.8	Loam
		20-50	--	32.4	46.6	12.7	8.3	Loamy sand
Pu312	6*	0-30	--	9.1	64.7	17.6	8.6	Sandy loam
Pu321	7*	0-30	11.75	7.9	40.3	29.0	22.8	Loam
Pu411	4*	0-10	24.67	2.9	40.1	33.6	23.4	Gravelly Loam
		10-30	--	3.3	36.63	31.3	28.8	Clay loam
		> 30	--	1.6	31.0	35.5	31.9	Clay loam
Pe111	22*	0-20	11.75	7.9	40.3	29.0	22.8	Loam
		20-50	--	32.4	46.6	12.7	8.3	Loamy sand
Pe121	23*	0-10	15.38	2.4	44.8	40.7	12.1	Gravelly Loam
		10-20	--	2.1	33.4	56.4	9.1	Silty loam
		20-35	--	25.5	45.3	22.8	6.4	Sandy loam
		35-70	--	21.4	57.6	9.9	11.1	Sandy loam
		70-100	--	18.7	43.5	25.2	12.6	Sandy loam
Pe211	9	0-30	--	8.1	29.7	32.7	29.5	Clay loam
		30-100	--	5.6	38.4	37.3	18.7	Gravelly Loam
	10*	0-10	17.29	11.2	58.7	19.4	10.7	Sandy loam
		> 10	--	18.3	30.0	27.2	24.5	Sandy clay loam
Pe221	8	0-5	16.54	7.5	40.6	28.8	23.1	Gravelly Loam
		5-15	--	5.8	65.8	16.5	11.9	Sandy loam
		15-30	13.73	6.3	59.6	25.1	9.0	Sandy loam
	24*	0-5	--	3.2	58.3	27.0	11.5	Sandy loam
		5-25	--	14.6	45.5	23.7	16.2	Sandy loam
		25-45	--	2.5	20.8	54.0	21.7	Silty loam
Pe311	14*	0-20	--	47.6	36.5	9.7	6.2	Loamy sand
		20-70	--	46.9	32.3	13.8	7.0	Loamy sand
		> 70	--	1.8	34.9	35.6	27.7	Clay loam
	16	0-5	--	3.5	41.4	30.6	31.5	Clay loam
		5-20	--	5.2	24.7	37.5	32.6	Clay loam
	17	0-5	--	2.9	45.6	29.4	22.1	Loam
		5-15	--	1.5	26.3	38.8	33.4	Clay loam
		> 15	--	1.4	29.8	32.1	36.7	Clay loam

Table 3. Cont.

Mapping unit symbol	Profile No.	Depth (cm)	Gravel content %	Particle size distribution %				Textural grade
				Coarse sand	Fine sand	Silt	Clay	
Pe321	18*	0-5	28.37	3.5	61.6	19.4	15.5	Gravelly Sandy loam
		5-30	--	38.1	45.4	9.7	6.8	Loamy sand
		30-50	32.79	28.9	46.3	13.6	11.2	Gravelly Sandy loam
		50-90	39.82	7.4	48.4	23.5	20.7	V. Gravelly Sandy clay loam
Pe411	15*	0-20	9.87	42.7	26.4	16.9	14.0	Sandy loam
		20-35	9.09	55.9	23.9	11.7	8.5	Loamy sand
		35-100	15.77	45.3	29.2	18.7	7.8	Gravelly Sandy loam
	27	0-10	13.04	27.4	51.7	13.3	7.8	Loamy sand
		10-30	--	14.9	67.8	10.0	7.3	Loamy sand
		30-65	--	18.2	40.5	29.1	12.2	Sandy loam
		> 65	24.08	76.4	11.6	7.2	4.8	Gravelly Sand
Pe511	26*	0-20	56.19	1.7	37.4	33.4	27.7	V.Gravelly Clay loam
		> 20	--	19.2	55.3	16.0	9.5	Sandy loam
Pe512	25*	0-20	56.22	1.9	37.3	35.5	25.3	V.Gravelly Clay loam
		20-30	--	20.1	54.5	16.0	9.4	Sandy loam
Pe513	28*	0-20	57.24	2.1	35.3	32.6	30	V.Gravelly Clay loam
		20-45	--	19.80	55.4	15.0	9.8	Sandy loam
Pe611	29*	0-20	56.22	5	38.3	28.3	28.4	V.Gravelly Sandy clay loam
		20-50	--	22.9	55.6	13.0	9.5	Sandy
Pl111	11*	0-30	--	1.6	21.0	29.4	48.0	Clay
		30-60	--	0.9	17.4	31.1	50.6	Clay
		60-120	--	0.7	11.9	32.1	55.3	Clay
Pl121	19*	0-20	9.87	42.7	26.4	16.9	14.0	Sandy loam
		20-35	9.09	55.9	23.9	11.7	8.5	Loamy sand
		35-100	15.77	45.3	29.2	18.7	7.8	Gravelly Sandy loam
Pl131	21*	0-25	--	8.2	27.8	35.6	28.4	Clay loam
		25-50	--	23.3	33.7	19.1	23.9	Sandy clay loam
Pl211	20*	0-25	--	8.2	27.8	35.6	28.4	Clay loam
		25-40	--	23.3	33.7	19.1	23.4	Sandy clay loam
Wa111	3*	0-15	9.16	27.5	57.3	8.9	6.3	Lamy sand
		15-35	3.98	8.4	60.4	20.7	10.5	Sandy loam
		35-70	--	25.2	34.9	26.5	13.4	Sandy loam
		> 70	--	7.9	45.3	29.0	17.8	Sandy loam

*=The model profile for each mapping unit.

Table 4. Some physical properties of the studied soils.

Mapping unit symbol	Soil profile No.	Depth (cm)	Bulk density (cm^3)	Hydraulic Conductivity (cm /h)	Soil moisture content %			Total porosity %
					Field capacity	Wilting point	Available water	
Pu211	1	0-5	1.59	17.89	14.19	4.73	9.46	42.15
		5-40	1.67	24.26	11.71	7.08	7.63	40.08
		40-60	1.69	25.03	10.78	3.87	6.91	39.52
		60-90	1.62	19.59	13.34	4.61	8.73	41.98
	2	0-10	1.51	14.52	16.97	6.89	10.08	48.36
		10-20	1.62	21.79	9.93	3.81	6.12	39.78
		20-50	1.51	13.68	17.31	6.79	10.52	48.09
		> 50	1.59	11.96	19.26	7.48	11.78	49.87
	5	0-10	1.57	13.08	15.45	5.41	10.04	42.05
		10-20	1.63	22.56	13.81	4.82	7.99	41.87
		20-35	1.69	24.79	9.95	3.67	6.28	40.82
		35-70	1.61	17.65	13.20	4.11	9.09	42.08
		> 70	1.60	12.81	14.92	5.07	9.85	41.90
	13*	0-15	1.58	24.65	10.37	3.64	6.73	39.72
		15-55	1.63	18.41	13.06	4.91	8.15	42.08
		55-90	1.64	15.36	16.56	6.69	9.87	46.04
		> 90	1.57	9.82	17.07	6.88	10.19	49.60
	12	0-20	1.38	8.89	19.04	8.14	10.90	50.11
		20-50	1.69	21.37	10.93	3.65	7.08	40.16
Pu312	6*	0-30	1.57	24.05	11.70	4.63	7.07	40.06
Pu321	7*	0 - 10	1.69	21.37	10.93	3.65	7.08	40.16
Pu411	4*	0-10	1.38	10.85	20.99	8.92	12.07	50.51
		10-30	1.34	9.15	24.05	9.15	14.90	51.76
		> 30	1.32	8.57	25.89	10.33	15.56	53.08
Pe111	22*	0 - 20	1.38	8.89	19.04	8.14	10.9	49.6
		20 - 50	1.69	21.37	10.93	3.65	7.08	40.16
Pe121	23*	0 - 10	1.57	13.08	15.45	5.41	10.04	42.05
		10 - 20	1.63	22.56	13.81	4.82	7.99	41.87
		20 - 35	1.69	24.79	9.95	3.67	6.28	40.82
		35 - 70	1.61	17.65	13.2	4.11	9.09	42.08
		70 - 100	1.6	12.81	14.92	5.07	9.85	41.9
Pe211	9	0-30	1.33	9.57	24.99	9.97	15.02	48.54
		30-100	1.54	12.06	20.59	8.72	11.87	43.29
	10*	0-10	1.58	21.90	12.88	4.38	8.50	40.87
		> 10	1.47	9.79	23.67	10.57	13.10	48.00
Pe221	8	0-5	1.41	9.78	19.18	8.46	10.72	49.01
		5-15	1.60	16.35	13.18	4.58	8.60	41.87
		15-30	1.62	21.69	12.16	4.35	7.81	40.95
	24*	0-5	1.60	20.85	13.20	4.31	8.89	42.08
		5-25	1.54	12.44	16.60	6.17	10.43	44.94
		25-45	1.47	10.08	19.73	7.95	11.78	46.25
Pe311	14*	0-20	1.67	25.98	10.68	3.83	6.75	38.75
		20-70	1.72	24.07	11.81	4.11	7.70	39.66
		> 70	1.41	9.83	25.00	10.88	14.12	49.81
	16	0-5	1.29	8.15	27.80	11.07	16.73	50.27
		5-20	1.34	7.89	28.90	11.81	17.09	51.81
	17	0-5	1.39	11.07	19.70	8.97	10.73	47.29
		5-15	1.35	7.12	28.63	10.96	17.67	51.36
		> 15	1.32	6.74	30.31	12.16	18.15	52.70
Pe321	18*	0-5	1.54	10.83	17.27	7.15	10.12	46.23
		5-30	1.69	23.37	11.43	3.98	7.45	39.80
		30-50	1.71	17.45	13.40	4.84	8.56	42.05
		50-90	1.48	11.81	17.95	7.97	9.98	44.11

*=The model profile for each mapping unit.

Table 4. cont.

Mapping unit symbol	Soil profile No.	Depth (cm)	Bulk density (cm^3)	Hydraulic Conductivity (cm /h)	Soil moisture content % at			Total porosity %
					Field capacity	Wilting point	Available water	
Pe411	15*	0-20	1.61	11.45	15.75	7.01	8.74	43.03
		20-35	1.72	21.33	12.60	4.61	7.99	40.17
		35-100	1.75	20.76	11.14	4.04	7.10	39.60
	27	0-10	1.64	26.51	14.81	4.03	6.78	40.11
		10-30	1.62	24.98	12.09	4.15	7.94	39096
		30-65	1.59	18.40	22.11	4.98	10.13	43.02
		> 65	1.74	25.61	11.00	3.72	7.28	39.25
Pe511	26*	0-20	1.35	10.22	23.65	9.77	13.88	47.81
		> 20	1.64	21.19	11.39	3.78	7.61	41.03
Pe512	25*	0 - 20	1.35	10.22	23.65	9.77	13.88	47.81
		20 - 45	1.64	21.19	11.39	3.78	7.61	41.03
Pe513	28*	0 - 20	1.35	10.22	23.65	9.77	13.88	47.81
		20 - 50	1.64	21.14	11.39	3.78	7.61	41.03
Pe611	29*	0 - 20	1.61	11.45	15.75	7.01	8.74	43.03
		20 - 50	1.64	21.19	11.39	3.78	7.61	41.03
Pl111	11*	0-30	1.14	1.97	42.99	16.29	26.70	55.90
		30-60	1.19	1.03	42.11	18.05	24.06	57.72
		60-120	1.23	0.85	43.89	21.11	22.78	61.55
Pl121	19*	0 - 20	1.61	11.45	15.75	7.01	8.74	43.03
		20 - 35	1.72	21.33	12.6	4.61	7.99	40.17
		35 - 100	1.75	20.76	11.14	4.04	7.1	39.6
Pl131	21*	0-25	1.34	9.54	23.62	8.95	14.67	49.26
		25-50	1.42	9.01	20.59	9.76	10.83	47.09
Pl211	20*	0 - 25	1.34	9.54	23.62	8.95	14.67	49.26
		25 – 40	1.42	9.01	20.59	9.76	10.83	47.09
Wa111	3*	0-15	1.66	23.74	10.75	4.05	6.70	39.56
		15-35	1.65	19.27	13.37	4.63	8.74	41.71
		35-70	1.66	12.38	14.78	5.05	9.73	43.04
		> 70	1.55	10.91	17.04	7.06	9.98	49.16

*=The model profile for each mapping unit.

Table 5. Chemical analysis of soil paste extract.

Mapping unit symbol	Profile No.	Depth (cm)	pH (1:2.5)	ECe (dS/m)	Soluble cations and anions (me/l)							
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO3^{-2}$	HCO_3^{-}	Cl^{-}	SO_4^{-2}
Pu211	1	0-5	7.61	2.12	13.50	3.14	5.13	0.6	--	2.96	11.76	7.65
		5-40	7.65	3.83	17.82	5.63	15.65	0.5	--	2.65	26.73	10.22
		40-60	7.79	13.95	38.88	25.60	70.93	0.8	--	2.97	117.60	15.64
		60-90	7.73	16.35	50.20	29.05	87.75	1.7	--	1.89	95.88	70.93
	2	0-10	7.87	4.42	28.70	7.74	9.62	0.46	--	2.98	21.56	22.00
		10-20	7.71	6.56	27.80	5.88	18.88	0.34	--	2.95	26.66	23.29
		20-50	7.45	7.09	36.48	5.12	29.19	0.28	--	2.16	30.04	38.87
		> 50	7.30	22.50	57.26	27.22	139.75	1.22	--	1.97	131.28	92.20
	5	0-10	7.86	11.60	32.40	14.60	71.86	0.84	--	1.95	67.24	49.98
		10-20	7.79	12.85	41.84	19.92	69.24	0.90	--	1.96	72.43	57.51
		20-35	7.67	13.42	43.10	19.22	73.11	0.77	--	1.77	79.19	55.24
		35-70	7.53	14.35	49.70	25.90	67.66	0.75	--	2.97	71.32	69.72
		> 70	7.24	24.46	90.20	28.60	133.55	1.35	--	1.98	150.17	101.35
	13*	0-15	7.67	4.95	20.38	8.94	21.50	0.78	--	2.85	25.48	23.27
		15-55	7.80	12.95	46.16	30.40	57.39	0.65	--	2.73	91.37	40.50
		55-90	7.60	14.40	53.72	30.12	63.86	0.50	--	2.56	85.87	60.47
		> 90	7.81	15.75	48.08	41.36	71.92	0.54	--	1.67	94.52	65.71
	12	0-20	7.74	16.20	40.76	27.64	95.69	0.81	--	1.94	95.10	67.86
		20-50	7.59	32.40	94.46	50.36	194.88	0.90	--	1.96	233.41	100.23
Pu312	6*	0-30	7.72	12.15	46.80	16.86	59.61	125	--	2.95	53.02	67.93
Pu321	7*	0-30	7.74	16.20	40.76	27.64	95.69	0.81	--	1.94	95.10	67.86
Pu411	4*	0-10	7.66	4.47	26.18	9.06	12.08	0.57	--	2.06	19.60	25.33
		10-30	7.51	9.63	40.60	20.66	37.32	0.46	--	2.10	41.64	55.60
		> 30	7.57	13.94	50.52	12.45	78.18	1.15	--	1.87	80.96	59.47
Pe111	22*	0-20	7.74	16.20	40.76	27.64	95.69	0.81	--	1.94	95.10	67.86
		20-50	7.59	35.56	94.46	50.36	194.88	0.90	--	1.96	233.41	100.23
Pe121	23*	0-10	7.86	11.60	32.40	14.60	71.86	0.84	--	1.95	67.24	49.98
		10-20	7.79	1.85	41.84	19.92	69.24	0.90	--	1.96	72.43	57.51
		20-35	7.67	13.42	43.10	19.22	73.11	0.77	--	1.77	79.19	55.24
		35-70	7.53	14.35	49.70	25.90	67.66	0.75	--	2.97	71.32	69.72
		70-100	7.24	24.46	90.20	28.60	133.55	1.35	--	1.98	150.17	101.35
Pe211	9	0-30	7.70	5.83	20.20	11.76	27.14	0.60	--	2.15	38.08	19.47
		30-100	7.81	6.15	26.08	6.40	29.20	0.42	--	2.36	42.28	17.46
	10*	0-10	7.67	13.50	44.72	24.77	67.37	1.04	--	1.95	95.56	40.59
		> 10	7.85	14.40	59.70	23.80	61.58	0.97	--	2.17	81.13	62.75
Pe221	8	0-5	7.41	14.40	52.38	25.10	66.99	1.58	--	2.90	77.48	65.67
		5-15	7.82	10.46	43.16	22.96	39.01	1.07	--	2.65	61.05	42.50
		15-30	7.63	7.20	28.88	18.72	26.30	0.50	--	2.90	48.66	22.84
	24*	0-5	7.80	13.56	45.08	10.44	82.12	0.96	--	2.16	103.24	33.20
		5-25	7.65	24.34	96.92	54.28	92.87	2.00	--	1.87	185.63	58.57
		25-45	8.01	27.55	52.92	25.08	199.00	2.1	--	197	226.40	50.73
Pe311	14*	0-20	8.03	5.85	23.46	14.62	22..10	0.72	--	2.86	36.66	21.38
		20-70	7.59	20.72	81.20	28.60	100.67	0.83	--	1.97	113.47	95.86
		> 70	7.12	24.46	91.32	40.20	116.22	0.76	--	1.95	130.01	116.54
	16	0-5	8.15	10.35	41.04	14.08	49.73	0.95	--	2.16	60.37	43.27
		5-20	8.32	15.30	63.72	16.88	75.91	0.79	--	1.95	89.11	66.24
	17	0-5	7.78	6.90	20.60	15.44	34.19	0.57	--	2.17	33.91	35.72
		5-15	7.65	8.72	39.68	17.40	31.97	0.85	--	1.96	41.40	46.54
		> 15	7.99	9.16	30.22	19.10	43.79	0.69	--	1.85	49.15	42.80
Pe321	18*	0-5	8.01	13.95	33.92	24.16	82.25	0.97	--	2.17	85.06	55.07
		5-30	7.69	14.16	59.53	21.33	63.22	0.62	--	2.15	77.43	65.12
		30-50	7.52	17.72	62.70	26.42	90.51	0.57	--	1.95	106.96	71.29
		50-90	8.11	19.87	73.03	30.70	97.47	0.50	--	1.87	112.86	86.97

*=The model profile for each mapping unit.

Table 5. cont.

Mapping unit symbol	Profile No.	Depth (cm)	pH (1:2.5)	ECe (dS/m)	Soluble cations and anions (me/l)							
					Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO3^{-2}$	HCO_3^{-}	Cl^{-}	SO_4^{-2}
Pe411	15*	0-20	7.63	3.10	14.06	6.12	12.52	0.50	--	2.95	14.19	16.06
		20-35	7.78	5.55	20.70	9.10	27.69	0.31	--	2.77	30.58	24.45
		35-100	7.65	10.35	40.50	12.02	52.30	0.28	--	1.98	63.62	39.50
	27	0-10	7.67	3.75	15.12	9.92	13.01	0.50	--	1.99	20.56	16.00
		10-30	7.63	4.85	17.22	1176	21.48	0.46	--	1.95	28.68	20.29
		30-65	7.72	5.85	23.50	9.02	27.48	0.35	--	2.96	33.64	23.75
		> 65	7.69	7.90	30.63	16.44	34.90	0.33	--	2.26	44.08	35.96
Pe511	26*	0-20	7.79	5.10	25.32	6.32	19.52	0.94	--	1.96	22.92	27.22
		> 20	7.41	6.30	25.10	8.58	29.12	0.77	--	2.56	29.20	34.81
Pe512	25*	0-20	7.79	5.10	25.32	6.32	19.52	0.63	--	2.17	28.16	20.32
		20-40	7.36	6.30	25.10	8.58	29.16	0.97	--	2.23	27.67	24.07
Pe513	28*	2-20	7.98	5.08	25.41	6.37	19.52	0.73	--	3.1	28.30	20.41
		20.45	7.36	6.42	25.07	8.61	29.16	0.97	--	2.20	27.67	24.11
Pe611	29*	0-20	7.81	5.05	25.41	6.40	19.61	0.67	--	2.20	28.31	20.36
		20-50	7.29	6.39	25.13	8.70	29.20	0.91	--	2.23	27.67	24.07
Pl111	11*	0-30	7.67	7.10	24.59	16.57	31.69	1.05	--	1.99	58.92	39.98
		30-60	7.62	4.06	13.69	6.98	19.83	0.55	--	2.12	22.22	16.71
Pl121	19*	0-20	7.63	3.10	14.06	6.12	12.52	0.50	--	2.95	14.19	16.06
		20-35	7.78	5.55	20.70	9.10	27.69	0.31	--	2.77	30.58	24.45
		35-100	7.65	10.35	40.50	12.02	52.30	0.28	--	1.98	63.62	39.50
Pl131	21*	0-25	7.70	11.28	31.19	18.99	64.11	0.80	--	2.05	65.14	47.90
		25-50	7.61	17.67	62.96	37.72	77.67	0.70	--	1.95	103.65	73.45
Pl211	20*	0-25	7.70	11.31	31.22	18.99	64.11	0.82	--	2.05	65.14	47.90
		25-40	7.61	17.71	62.96	37.81	77.72	0.75	--	1.95	103.65	73.45
Wa111	3*	0-15	7.58	4.20	15.24	7.20	20.58	0.56	--	2.87	21.57	19.36
		15-35	7.73	11.64	37.78	22.30	58.57	1.05	--	1.90	68.81	48.99
		35-70	7.37	14.42	55.36	7.68	84.79	0.77	--	2.07	82.61	63.92
		> 70	7.12	17.04	59.13	26.07	89.76	1.94	--	1.89	96.82	78.19

*= The model profile for each mapping unit.

Table 6. Some chemical properties of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	$CaCO_3$ content %	Organic matter %	Gypsum content %	Iron oxides %	Cation exchange capacity (me/100 soil)	Exchangeable Na %
Pu211	1	0-5	3.38	0.11	--	--	8.64	3.15
		5-40	4.51	0.07	--	3.37	3.84	5.76
		40-60	7.83	0.05	--	0.57	2.88	9.82
		60-90	8.96	0.08	--	4.86	7.65	11.03
	2	0-10	9.23	0.12	--	--	10.39	4.87
		10-20	5.38	0.07	--	5.45	4.81	6.29
		20-50	6.32	0.11	9.26	3.12	9.95	7.02
		> 50	2.97	0.12	16.74	--	12.23	10.61
	5	0-10	8.92	0.10	--	--	8.17	8.58
		10-20	6.13	0.09	--	--	6.01	2.24
		20-35	12.06	0.07	--	--	4.22	8.01
		35-70	19.57	0.08	4.28	--	6.49	10.25
		> 70	23.80	0.06	8.49	--	7.51	12.63
	13*	0-15	2.90	0.09	--	0.67	5.43	5.74
		15-55	7.26	0.11	--	1.92	7.08	9.37
		55-90	21.53	0.08	7.65	--	9.18	10.11
		> 90	8.19	0.09	12.38	--	11.54	12.56
	12	0-20	7.96	0.16	--	--	14.97	9.10
		20-50	10.65	0.08	2.45	6.43	5.76	14.64
Pu312	6*	0-30	6.35	0.09	1.36	--	5.76	8.18
Pu321	7*	0-30	10.67	0.10	2.50	6.43	5.77	14.64
Pu411	4*	0-10	2.54	0.15	--	--	15.64	3.40
		10-30	6.69	0.17	7.67	3.85	18.97	7.74
		> 30	7.85	0.13	1.82	--	2.85	9.46
Pe111	22*	0-20	7.96	0.16	--	--	14.97	9.10
		20-50	10.65	0.08	2.45	6.43	5.76	14.64
Pe121	23*	0-10	8.92	0.11	--	--	8.17	8.85
		10-20	6.18	0.10	--	--	6.04	2.42
		20-35	12.06	0.09	--	--	4.31	8.06
		35-70	19.61	0.06	4.28	--	6.94	10.26
		70-100	23.80	0.05	8.5	--	7.51	12.65
Pe211	9	0-30	2.20	1.32	--	--	19.65	4.05
		30-100	5.16	0.87	--	3.72	13.06	5.20
	10*	0-10	5.18	0.12	--	1.79	7.09	8.56
		> 10	9.23	0.015	8.07	4.88	16.84	9.75
Pe221	8	0-5	12.28	0.14	4.15	--	16.01	9.37
		5-15	8.06	0.09	--	--	7.98	7.42
		15-30	2.12	0.07	--	3.47	5.76	5.66
	24*	0-5	9.76	0.11	--	--	7.45	10.06
		5-25	1.94	0.13	--	6.86	10.70	12.97
		25-45	12.15	0.10	--	7.79	14.60	11.88
Pe311	14*	0-20	11.65	0.08	--	--	4.26	6.17
		20-70	9.27	0.06	10.79	3.06	4.80	11.95
		> 70	8.19	0.12	18.82	6.25	18.75	12.86
	16	0-5	16.11	0.23	--	--	14.58	7.35
		5-20	32.57	0.19	5.27	2.72	15.72	10.07
	17	0-5	8.25	0.47	--	--	14.65	6.35
		5-15	11.84	0.39	6.78	--	7.05	8.41
		> 15	13.58	0.16	--	3.08	19.64	10.80
Pe321	18*	0-5	11.55	0.12	--	--	10.44	7.16
		5-30	7.21	0.07	4.85	1.78	4.70	7.87
		30-50	9.04	0.05	9.47	--	7.85	8.76
		50-90	17.39	0.09	13.80	--	11.09	11.02
Pe411	15	0-20	1.29	0.11	--	--	8.89	3.95
		20-35	7.89	0.08	--	--	5.07	4.08
		35-100	2.54	0.06	--	--	4.89	7.13
	27*	0-10	3.42	0.11	--	--	5 .05	3.79
		10-30	2.89	0.07	--	--	4. 89	4.07
		30-65	6.21	0.18	--	--	7.87	6.35
		> 65	6.32	0.09	--	--	3.62	7.89

Table 6. Cont.

Mapping Unit Symbol	Profile No.	Depth (cm)	$CaCO_3$ content %	Organic matter %	Gypsum content %	Iron oxides %	Cation exchange capacity (me/100 soil)	Exchangeable Na %
Pe511	26*	0-20	9.50	0.17	6.78	--	17.84	5.45
		> 20	2.28	0.09	14.83	--	6.43	7.80
Pe512	25*	0-20	9.50	0.20	6.78	--	17.91	5.45
		20-30	2.31	0.11	14.83	--	6.34	7.86
Pe513	28*	0-20	9.50	0.13	6.78	--	17.91	5.43
		20.45	2.28	0.06	14.91	--	6.36	7.70
Pe611	29*	0-20	9.60	0.09	6.79	--	17.89	5.44
		20-50	2.30	0.11	14.85	--	6.42	7.83
Pl111	11*	0-30	2.19	1.82	--	--	31.72	6.64
		30-60	1.67	1.05	--	--	33.89	4.92
Pl121	19*	0-20	1.31	0.09	--	--	8.89	3.95
		20-35	7.91	0.06	--	--	5.11	4.11
		35-100	2.60	0.11	--	--	4.89	7.20
Pl131	21*	0-25	6.73	0.36	--	--	18.12	9.28
		25-50	13.48	0.14	1.94	--	12.78	11.04
Pl211	20*	0-25	6.70	0.41	--	--	19.01	9.30
		25-40	13.51	0.15	1.94	--	12.87	11.06
Wa111	3*	0-15	1.88	0.08	--	--	4.35	3.21
		15-35	6.27	0.07	--	--	6.55	7.15
		35-70	5.81	0.09	11.57	0.94	8.91	9.04
		> 70	3.95	0.07	17.08	--	11.67	11.68

Table 7. The available content of macronutrients in the studied soils.

Mapping Unit Symbol	Soil profile	Depth (cm)	Macro nutrients (mg/kg)		
			N	P	K
Pu211	1	0-5	6.7	2.1	54.8
		5-40	3.2	1.4	42.6
		40-60	2.4	1.5	36.1
		60-90	4.9	1.8	49.5
	2	0-10	10.7	2.9	89.3
		10-20	5.1	1.8	52.4
		20-50	9.5	2.7	81.1
		> 50	9.8	2.9	117.8
	5	0-10	7.2	2.6	67.8
		10-20	5.6	1.8	57.1
		20-35	3.9	1.4	41.9
		35-70	5.8	2.1	76.5
		> 70	5.6	2.2	87.1
	13*	0-15	5.2	1.9	52.4
		15-55	5.4	2.0	63.9
		55-90	5.1	1.8	77.1
		> 90	4.9	2.0	111.6
	12	0-20	10.7	3.1	156.3
		20-50	4.9	1.6	52.1
Pu312	6*	0-30	6.2	2.3	61.5
Pu321	7*	0-30	10.7	3.1	156.3
Pu411	4*	0-10	14.2	4.4	218.3
		10-30	18.6	8.9	237.6
		> 30	17.5	9.1	259.9
Pe111	22*	0-20	10.7	3.1	156.3
		20-50	4.9	1.6	52.1
Pe121	23*	0-10	7.8	2.7	67.8
		10-20	5.6	2.1	56.1
		20-35	1.1	1.6	40.9
		35-70	5.8	1.90	77.3
		70-100	6.1	2.3	85.3
Pe211	9	0-30	17.7	9.2	261.9
		30-100	9.1	3.8	169.2
	10*	0-10	6.3	2.2	57.7
		> 10	12.9	4.1	227.5
Pe221	8	0-5	13.7	4.2	221.9
		5-15	6.6	2.3	63.5
		15-30	5.8	1.9	53.7
	24*	0-5	6.3	2.2	59.8
		5-25	8.5	2.6	74.4
		25-45	9.8	2.9	167.3

*=The model profile for each mapping unit**.**

Table 7. cont.

Mapping Unit Symbol	Soil profile	Depth (cm)	Macronutrients (mg/kg)		
			N	P	K
Pe311	14*	0-20	4.2	1.5	44.9
		20-70	3.9	1.4	46.5
		> 70	7.1	1.6	218.6
	16	0-5	16.5	8.9	252.7
		5-20	12.8	7.7	303.1
	17	0-5	17.9	6.4	378.6
		5-15	21.6	8.9	462.7
		> 15	14.2	7.6	478.5
Pe321	18*	0-5	8.7	2.8	81.5
		5-30	4.1	1.9	58.2
		30-50	4.3	2.0	61.7
		50-90	4.7	1.8	146.9
Pe411	15*	0-20	9.2	2.7	81.5
		20-35	5.1	1.7	55.6
		35-100	3.5	1.1	48.7
	27	0-10	8.9	3.9	71.5
		10-30	5.1	1.7	49.4
		30-65	5.3	1.8	62.9
		> 65	2.4	1.1	33.5
Pe511	26*	0-20	13.6	6.7	253.4
		> 20	5.7	2.4	63.8
Pe512	25*	0-20	13.6	6.8	253.3
		20-30	6.1	2.1	69.8
Pe513	28*	0-20	13.9	6.3	254.1
		20-45	5.89	2.2	65.1
Pe611	29*	0-20	12.98	6.4	252.9
		20-50	6.25	2.25	67.1
Pl111	11*	0-30	67.6	19.8	992.2
		30-60	59.8	11.6	817.5
		60-120	48.5	9.3	786.4
Pl121	19*	0-20	9.2	2.7	82.1
		20-35	5.2	1.6	84.9
		35-100	3.6	1.3	48.5
Pl131	21*	0-25	32.7	9.8	248.5
		25-50	16.4	5.6	209.1
Pl211	20*	0-25	32.5	9.8	248.4
		25-40	16.3	5.7	209.1
Wa111	3*	0-15	4.4	1.8	45.8
		15-35	5.9	2.0	61.2
		35-70	6.1	2.2	79.5
		> 70	8.2	1.9	176.3

*=The model profile for each mapping unit

3.3 Soils of the study area

To satisfy and meet the objectives of the present study, geopedomorphic map "soil map" of the studied area was conducted first throughout the integration of physiographic interpretation of satellite image which overlaid on a digital elevation model DEM created on the GIS.

The geopedological map and its legend, is shown in Map (3) and Table (1). The legend represents the hierarchical structure of the geo-pedomorphic units. Four landscapes are presented in the area; plateau, piedmont, plain and Wadi.

As shown in the legend, the modal profile for the unit is indicated through which all the main soil characteristics is extracted for the map unit and stored within the GIS as a geographic database. Percentage of the main soils and their associations were estimated during the field studies.

Map 4, shows the soil classification of the study area as attribute map .

Plate 1. Petrogypsic horizon exposed on the soil surface beside profile 26

Plate 2. Gypsiferous flat summit on Pe511 map unit.

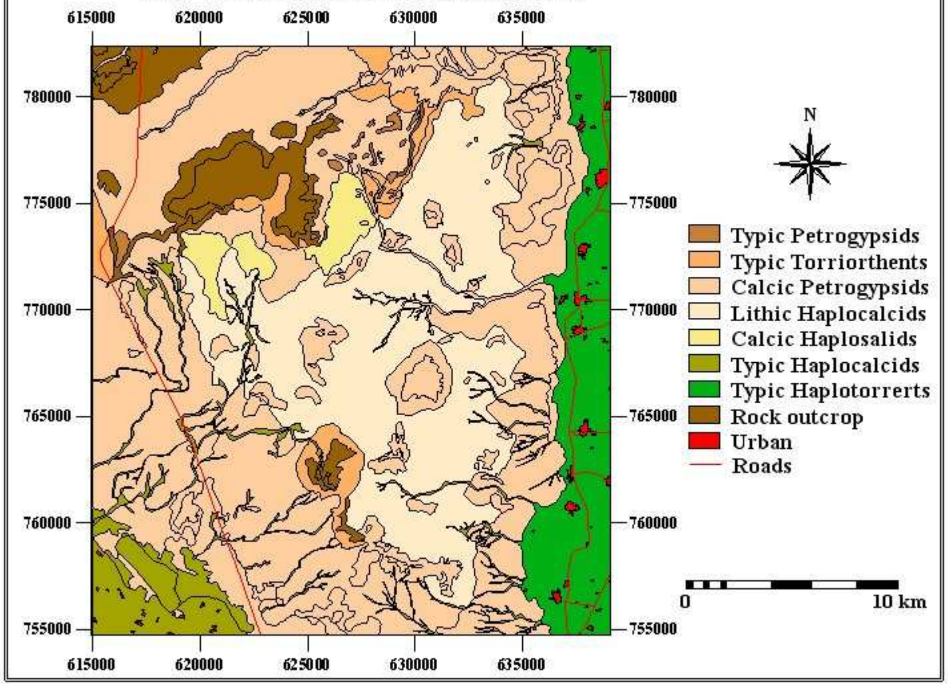
3.4 Land capability assessment.

Quantitative estimation of environmental conditions and soil properties such as A: (soil profile depth) , B: (texture, permeability, available water), C: (slope), X: (drainage, $CaCO_3$, gypsum, salinity and alkalinity) were used for the numerical land evaluation, California Storie index, Roy H. Bowman et al, (1973). The studied soil profiles were placed into classes according to their calculated capability indices. The calculated capability rating indices are presented in Table 8 and Map 5. The data showed that the soils of the investigated area were placed in classes 3, 4 and 5.

3.5 Land evaluation

The following main steps were done for performing land evaluation of the study area:
1) selecting and describing land use types, 2) deciding on land use requirements and factor ratings, 3) preparing the relevant land qualities and land characteristic for each land map unit and finally, 4) matching land use requirements with land qualities using the Automated Land Evaluation Systems (ALES), 5) displaying the results as maps in ILWIS GIS. Table 9, summarize the tested land use types.

Map 4. Soil classification of the study area.



Map 5. Soil capability grades for intensive agriculture.

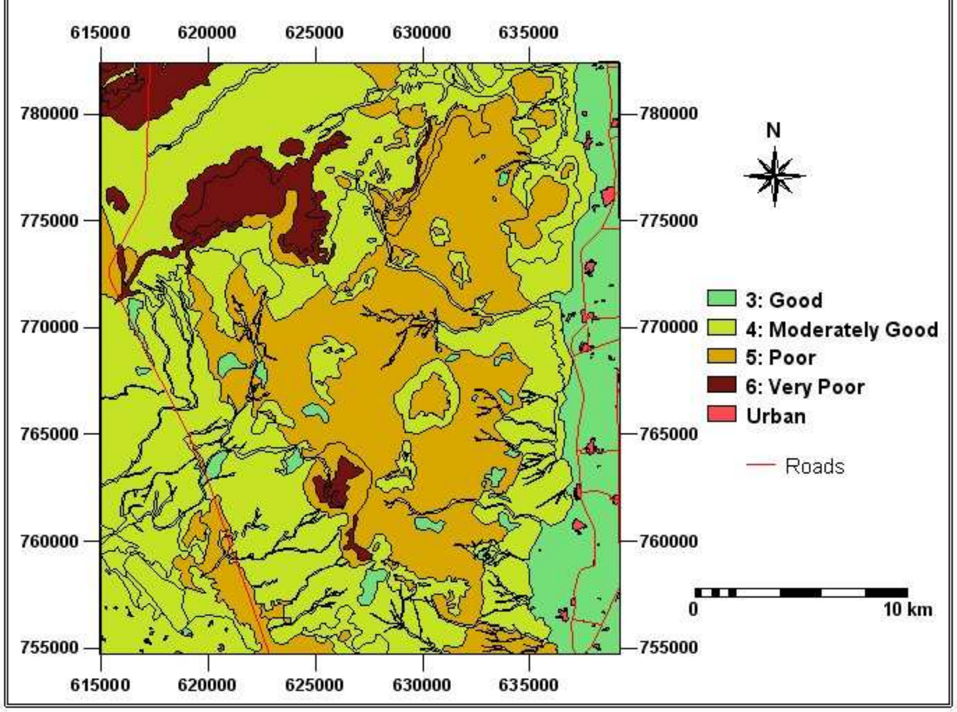


Table 8. Capability rating indices and capability classes.

Map unit	Rating index	Capability Class	Area (Faddan)
Pu111	**N.A.***	**6- Very Poor**	**722.2**
Pu121	**N.A.**	**6- Very Poor**	**6374.9**
Pu211	**28.22**	**4- Moderately Good**	**18020.9**
Pu311	**N.A.**	**6- Very Poor**	**2737.4**
Pu312	**18.29**	**5- Poor**	**4694.2**
Pu321	**11.81**	**5- Poor**	**716.7**
Pu411	**12.32**	**5- Poor**	**656.3**
Pe111	**20.35**	**4- Moderately Good**	**3502.7**
Pe121	**25.22**	**4- Moderately Good**	**1218.5**
Pe211	**27.64**	**4- Moderately Good**	**3624.2**
Pe221	**15.47**	**5- Poor**	**35039**
Pe311	**20.81**	**4- Moderately Good**	**34651.9**
Pe321	**15.01**	**5- Poor**	**4133.1**
Pe411	**29.34**	**4- Moderately Good**	**3601.8**
Pe511	**17.15**	**5- Poor**	**3338.2**
Pe512	**30.47**	**4- Moderately Good**	**8336.8**
Pe513	**41.67**	**3-Good**	**2193.5**
Pe611	**34.58**	**4- Moderately Good**	**830.5**
Pl111	**42.25**	**3-Good**	**16436.1**
Pl121	**36.68**	**4- Moderately Good**	**1435.7**
Pl131	**23.75**	**4- Moderately Good**	**3451.9**
Pl211	**21.76**	**4- Moderately Good**	**1129.4**
Wa111	**21.28**	**4- Moderately Good**	**2222.4**

N.A.*: Not applicable

Table 9. Selected land use types.

Land use type	Cultivation period	Land use descriptive name
LUT1	Summer	**cotton** followed by clover
LUT2	Winter	**wheat / barley** followed by maize or sorghum
LUT3	Summer	**sorghum** followed by wheat, clover or vegetables
LUT4	Winter	**sugar beet** followed by summer crop
LUT5	Summer	**onion** followed by winter crop
LUT6	Winter	**chamomile** followed by summer crop
LUT7	Permanent	**olive** mostly intercropped with date palm
LUT8	Permanent	**citrus** mostly lemon

Figure 2. Land suitability for wheat, sugar beet, sorghum and cotton.

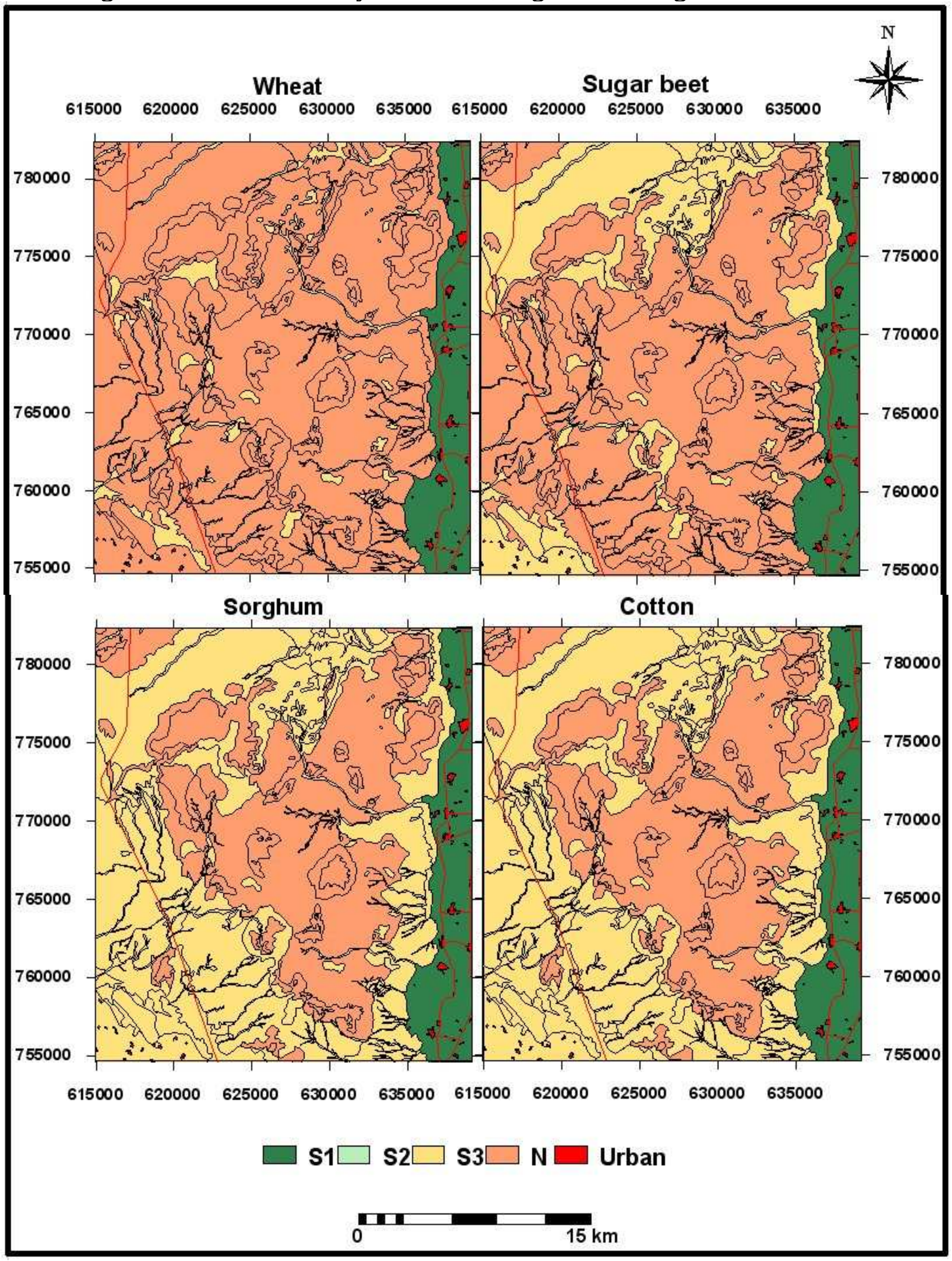


Figure 3. Land suitability for chamomile, onion, olive and citrus.

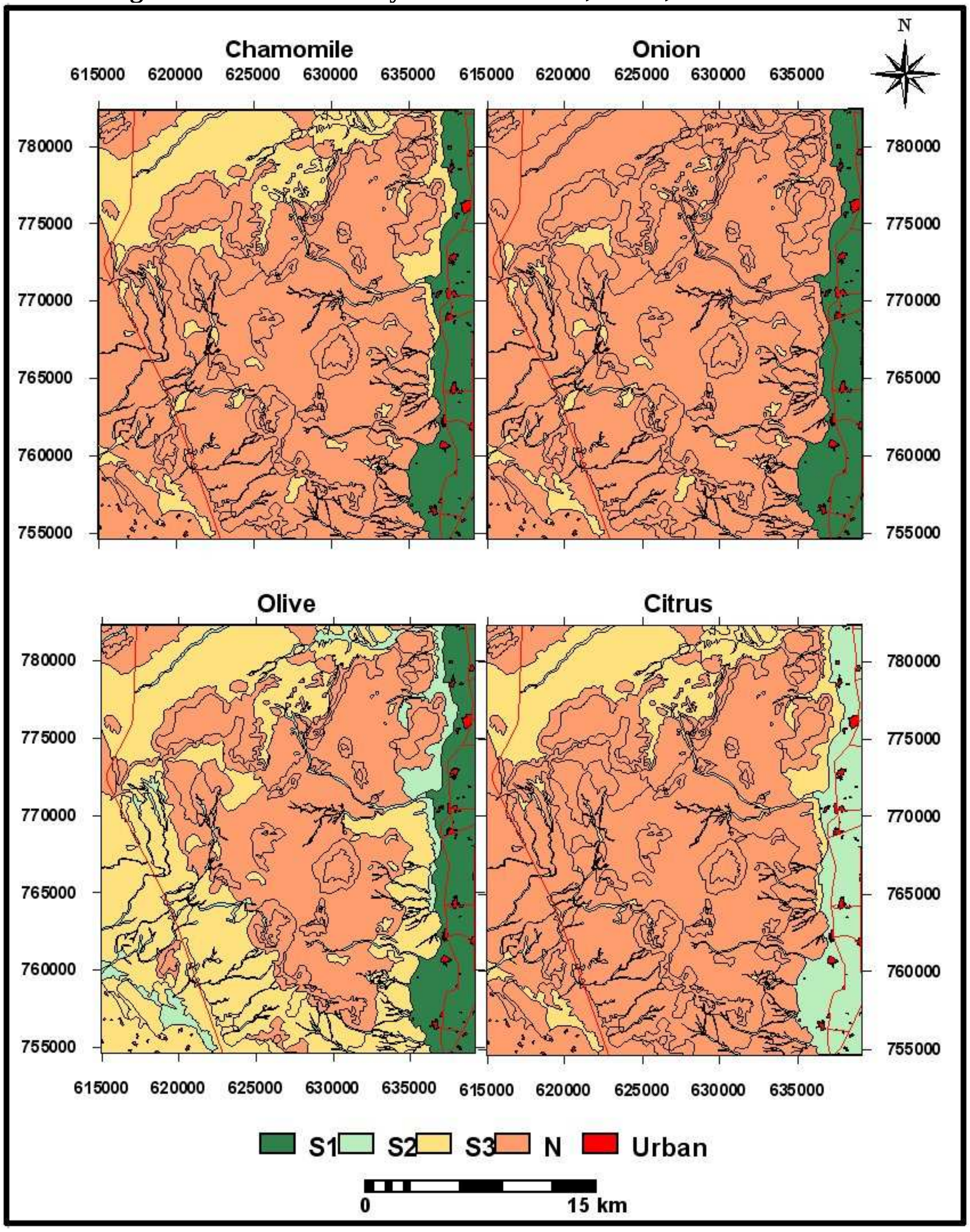


Table 10. Suitability areas for the selected land uses.			
Cotton		**Onion**	
Suitability Class	**Area (Feddan)**	**Suitability Class**	**Area (Feddan)**
S1	**16436.1**	**S1**	**16436.07**
S2	**0.0**	**S2**	**0.0**
S3	**90917.7**	**S3**	**20392.80**
N	**51714.3**	**N**	**122239.27**
Wheat		**Chamomile**	
S1	**16436.07**	**S1**	**16436.07**
S2	**0.0**	**S2**	**0.0**
S3	**22615.20**	**S3**	**25146.34**
N	**120016.87**	**N**	**117485.731**
Sorghum		**Olive**	
S1	**16436.07**	**S1**	**16436.07**
S2	**0.0**	**S2**	**10884.10**
S3	**94255.92**	**S3**	**65629.55**
N	**48376.15**	**N**	**66118.42**
Sugar beet		**Limon**	
S1	**16436.07**	**S1**	**0.0**
S2	**0.0**	**S2**	**17871.80**
S3	**49911.54**	**S3**	**27469.27**
N	**92720.54**	**N**	**113727.07**

The land use requirements are the independent variables of the land evaluation model. In the FAO framework for land evaluation, land utilization types have one or more land use requirements, which are matched with the corresponding land qualities (Rossiter and Wambeke, 1997). The most relevant land use requirements "land qualities and their diagnostic factors" were selected for each land use type, on the basis of the available bibliography and the information collected during the fieldwork. A review was made taking into account the effects of the land qualities and diagnostic factors upon the use. The requirement tables were prepared, for which some reference books and publications were used such as, FAO (1976), Siderius (1992) and Sys et al. (1993). There is no doubt that land use requirement tables have to be adapted and adjusted for the studied area, Gomaa (2004). The procedure of factor ratings applied on this model was to set up values which indicate how well each land use requirement is satisfied by particular conditions of the corresponding land qualities, i.e. the suitability of the land quality for a specific land use type. Factor rating was done in this study in terms of four classes as follows: S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable, N = not suitable. The suitability areas for the selected land uses are shown in Table 10 and Figures 2 &3.

4. CONCLUSIONS

- The southern and eastern parts of the studied area are moderately suitable for agriculture, whereas, the middle parts are mostly classified as marginally or not suitable due to their salinity and cementation constraints.
- Due to elevation limitation and limited irrigation water in Tamia District, Fayoum Governorate, it is recommended to connect the eastern northern parts of the study area with a direct irrigation canal from El Ayat District, Giza Governorate.

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تقييم بعض الأراضى شرق محافظة الفيوم والمتاخمة لطريق أسيوط الصحراوى، مصر

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الملخص

أجري هذا البحث على الأراضي شرق محافظة الفيوم، والمتاخمة لطريق مصر–أسيوط الصحراوى. وهدفت الدراسة إلى إجراء حصر نصف تفصيلي لأراضي المنطقة بالاستعانة بصور الفضاء لاندسات وأنظمة المعلومات الجغرافية وذلك لإجراء تقييم طبيعى لوحدات التربة الفيزيوجرافية لتقدير القدرة الإنتاجية للأراضي وأقتراح التركيب المحصولى الملائم للأراضى التي تصلح للزراعة وذلك بالإستعانه ببرنامج ILWIS لأنظمة المعلومات الجغرافية وبرنامج ALES لتقييم التربة الآلى. وقد تم أولا تفسير مرئى لصور الفضاء المتراكبة فوق نموذج الطبوغرافية الرقمى وذلك لإنتاج خريطة التربة الجيوبيدولوجية والتى تم التحقق من وحداتها فى الحقل، ثم تم تمثيل وحدات التربة بعدد 29 قطاع أرضى ووصف القطاعات الأرضية وتقدير الصفات الطبيعية والكيماوية للعينات الممثلة ثم تخزين البيانات فى قاعدة بيانات جغرافية. ولقد تم تقسيم الأراضي على أساس نظام التقسيم الأمريكي USDA Soil Taxonomy حتى مستوى تحت المجموعة ، وكانت مجموعات الأراضى الرئيسية بالمنطقة هى : Petrogypsids, Haplocalcids, Haplosalids, Torriorthents and Haplotorrerts . وقد تم إجراء تقييم للقدرة الإنتاجية لأراضى المنطقة ثم إجراء تقييم طبيعي للأراضي الصالحة لاختبار مدى ملائمتها للزراعات المختلفة طبقاً للإطار العام لمنظمة الأغذية والزراعة "FAO" والاستعانة ببرنامج ILWIS لنظم المعلومات الجغرافية لإنتاج الخرائط. وقد تم الأخذ فى الاعتبار خمس صفات تربة تستلزمها استخدامات الأرض المقترحة; وهى الملوحة والقلوية ، توفر العناصر الغذائية ، توفر الرطوبة ، توفر الأكسوجين ، وظروف مجال الجذور. وقد أشارتْ النَتائِجُ بأنّ الأجزاءَ الشرقيةَ والمتوسّطةَ والجنوبيةَ للمنطقةِ تُصنّفُ كمتوسطة الملائمة. بينما الأجزاء الشمالية تصنف في الغالب على إنها هامشية أَو لَيستْ مناسبةَ بسبب قيودِ الملوحةِ والإلتحامات بالتربة.

الكلمات الدالة:

تقييم الأراضي، أراضي شرق الفيوم ، نظم المعلومات الجغرافية ،الزراعة المستدامة ، إدارة الأراضي والمياه ، أنماط استخدام الأرض.