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The use of RS and GIS for Assessment of Wadi El- Assiuty Soils, Egypt

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Abstract

The current study area is part of Wadi El- Assiuty, Assiut, Egypt. It is one of the most promising developed areas in Egypt. It lies in the eastern desert of Assiut city. It is located between longitudes 31°18' and 31°48' E and latitudes 27°10' and 27°45' N. The study aims to generating a semi-detailed soil map that is suitable to achieve a land capability evaluation of Wadi El- Assiuty soils using "ILWIS"-GIS.

Visual interpretation was first undertaken on an enhanced natural color composite landsat TM image and overlaid on Digital Elevation Model (DEM) for the preparing of geo-pedological soil map using the 3D GIS capabilities. The mapping units of the study area were strictly verified in the field where19 soil profiles were selected to represent the different mapping units. The soil profiles were carefully described and representative the soil samples were taken from each profile. Then, 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 level according to the protocol of the United States Department of Agriculture (USDA Soil Taxonomy, 2014a). The main soil sub groups that were investigated in the study area were; Typic Haplocalcids and Typic Haplosalids.

California Storie index, (Storie, 1978) and O'Geen *etal.* (2008) are used to rate the soil capability for intensive irrigated agriculture. The results were displayed as maps using "ILWIS"-GIS.

Results indicated that the area currently lacks the high capability class. However, three soil capability classes of C2, C3 and C4 were recognized in the study area. About 32493.60 feddans (29.9% of the evaluated soils) are moderately capable, 73387.14 feddans (67.3%) are marginally capable and 3156.26 feddans (2.9%) indicating limited capability. A potential capability map was also produced after eliminating the correctable limitations, by improving the soil properties some of these soils can approach potential capability. The results show that 67.3% of the total study area is potentially suitable for agriculture.

From this study, it is recommended to improve the current capability of the studied soils by applying soil management practices that include:

- Adding organic and chemical fertilizers to improve moisture availability, nutrient availability and CEC.
- Executing a leaching process for removing the excess of soluble salts.
- Using modern irrigation systems to reduce the irrigation periods to avoid salts accumulation and the formation of soil crust in the calcareous soils.

Keywords: *Soil Capability, Potential Soil Capability, RS, GIS, ILWIS and Wadi El- Assiuty soils.*

Introduction

Egypt suffers from high population growth and continued decline of farmland per capita. Agricultural extension in the desert areas is one of the main objectives of the national agricultural expansion plan in Egypt. Therefore, it is necessary to explore the different available land resources, assess their potentiality for viable agriculture and plan the suitable sustainable land use. Wadi El-Assiuti is one of the promising areas for land reclamation due to its location nearby the urban areas of Assuit and its agricultural potentiality, Faragallah (1995) and Abdel- Aziz (1998). Wadi Al Assiuti is one of the largest dry wadis in middle Egypt, with a remarkable dry drainage which its whose main channel reaches about 186 Km in length (Belal *etal.,* 2015). Many private sector investments already paid efforts in reclaiming soils at Wadi El-Assuiti. It is the duty of soil scientists to survey such new lands and to map the most potential areas for the reclamation andmanagement of such soils. Geographic Information system (GIS) and Remote Sensing (RS) are successfully proved as very powerful tools to facilitate establishing spatial soil mapping units and handle vast geographical databases.

The present work aims mainly to apply the remote sensing and GIS techniques to investigate land resources in Wadi El-Assuiti area, and assess their capability for agriculture.

General Description of the Study Area

The location understudy is a part of the eastern desert, east of Assiut city. Wadi El-Assiuiti is bordering Assiut governorate from the eastern side. It is the largest and greatest dry valley which runs in Sahara desert for a distance of about 115 Km. However, its width varies from 5 to 25 Km (Salama *et al.*, 2014). The area under investigation is located about 20 Km northeast of Assiut city. It lies between latitudes 27°10' and 27°45' N, and longitudes 31°18' and 31°48' E. The total study area covers about 450 Km^2. Figure, 1 shows the location map of the study area that is displayed on the geological map of Assiut.

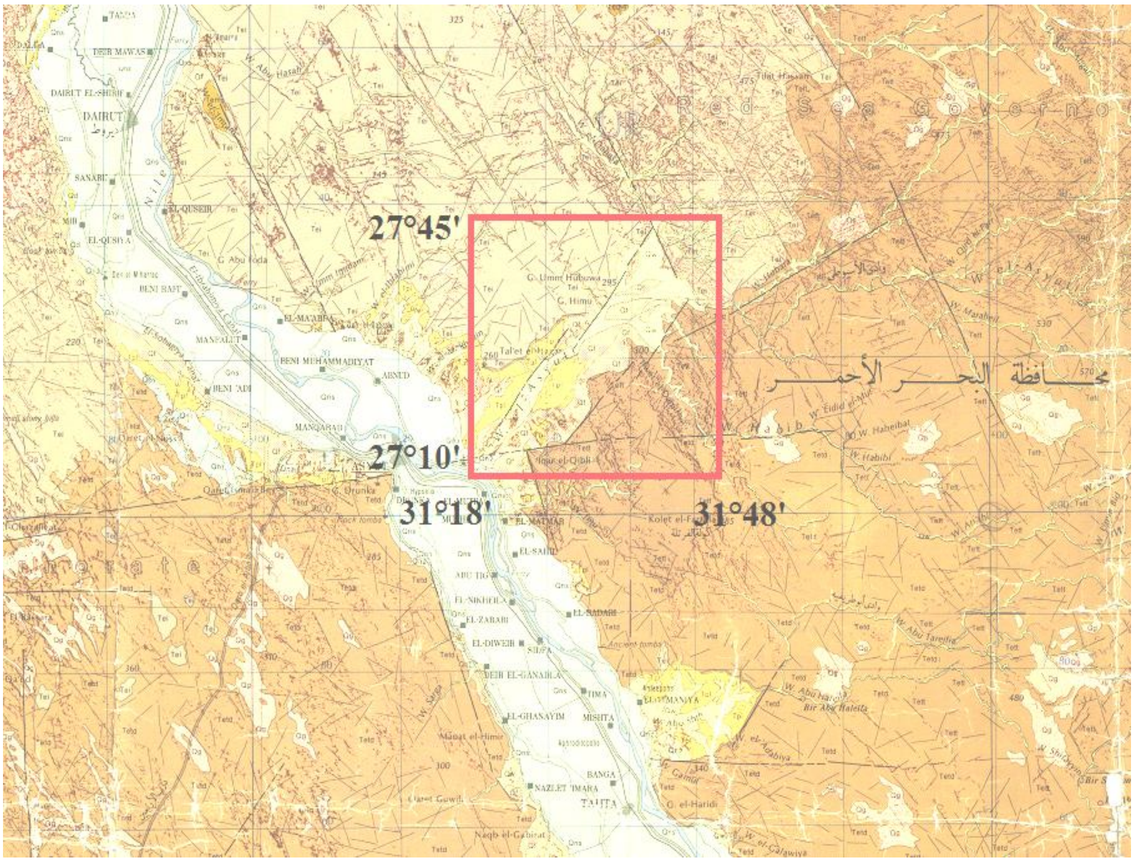

Figure 1. A location map of the study area that is displayed on the geological map of Assiut.

The area is characterized by a hot and dry summer with scanty winter rainfall and bright sunshine throughout the year. In general, the rainfall in the eastern desert of Egypt is very rare and occurs mainly from cyclonic winter storms that may occur once every 10 to 20 years (Belal *et al.,* 2015). Meteorological data obtained from the Assiut University station at Assiut, through the last ten years (2003-2012) showed that the temperature is regular in its seasonality. The lowest average temperature through the last ten years was 8°C recorded in January while the highest average was 39°C and was found in July. The highest mean relative humidity in the study area was 50% recorded in December and the lowest onewas 24% in May (Salama *et al*., 2014).

Topographic elevation in the southeastern part of the limestone plateau range from 195 to 330 meters above sea level, where as in the northwestern part, they range from 257 to 330 meters above sea level. Elevations of the Wadi El-Assiuti range from 65 to 137 meters, decreasing the southwestward along Wadi El-Assiuti (Bakheit, 1983 and Khalil, 1988). Different geological, geophysical and hydrological studies were carried out by many authors on the study area and its neighborhood such as said (1962), El-Gamili (1964), Youssef *etal*. (1977), Elbassyony (1978), Bakheit (1989), Rizkalla (1989), Faragallah (1995), Abdel- Aziz (1998) and Araffa *etal.* (2015).

Stratigraphically, Wadi El-Assiuti is mainly covered by pilo-Pleistocene sediments concealing lower Eocene bed rock. It is bounded by the Eocene limestone scarps from the north, south and east and by the Nile flood plain from the west. The Wadi drains southwest ward into Nile River, (Said, 1981 and 1990; Mansour and Philobbes, 1983).

Materials and Methods

The work of this study was conducted since 2012 using the following stages:

1 Satellite data interpretation and GIS application

2 Field work and laboratory analysis

3 Coding soil database attributes and Soil map generation

4 Land capability assessment.

1. Satellite Data Interpretation and GIS Application:

1.1. Geometric correction and registration:

The topographic map scale 1:50,000 (EGSA, 1997) was first scanned with 250 dpiresolution, imported into "ILWIS"-GIS and then, geometrically corrected using polynomial order 1, Transverse Mercator projection and Helmert 1906 Spheroid. After wards, it was re-projected into an ETM projection system. The georeferenced topographic map was used for projecting the TM image (dated April, 2002) of the study area to the ETM system, using image-to-image geometric correction module in "ILWIS"-GIS. It wasused for digitizing the contour, roads and urban layers.

1.2. Satellite data processing and information extraction:

Stretching, contrast enhancement and an enhanced false color composite of bands (7, 4 and 1) of Landsat image were applied, and visually interpreted on the screen after overlaying the image on the digital elevation model in a 3D for the study area. Then, the main landscape and the different physiographic mapping units were defined.

The following maps were accurately created using "ILWIS"-GIS

- The contour line and spot height map which was digitized from topographic maps1:50000 scale with 1 meter intervals accuracy (EGSA, 1997).

- Digital Elevation Model (DEM), was made by interpolating the contour lines and spot heights using ILWIS map-calculation formulas. The contour map was imported to "ARCVIEW"-GIS where the 3D model is created.

- Slope map which was created from the DTM map using "ILWIS"-GIScapabilities.

- Roads network was digitized directly from the topographic map with scale1: 50000.

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

2. Field Work, Laboratory Analysis

A general reconnaissance survey was first carried out throughout the study area using intensive testing auger samples and then, the transect sampling method is applied to cross the different mapping units in the area. Nineteen soil profiles were examined, (Fig. 2). Detailed morphological description was recorded for each studied soil profiles, on the basis outlined by FAO (2006) and Soil Survey Staff (2014a). The exact locations were recorded using a handheld GPS. The description summary of the studied soil profiles is shown in Table 2.

The collected soil samples (total number of 72 disturbed samples) were air-dried; gently ground, and sieved through 2 mm sieve. Then, the main physical and chemical properties were determined (Soil Survey Staff, 2014b).

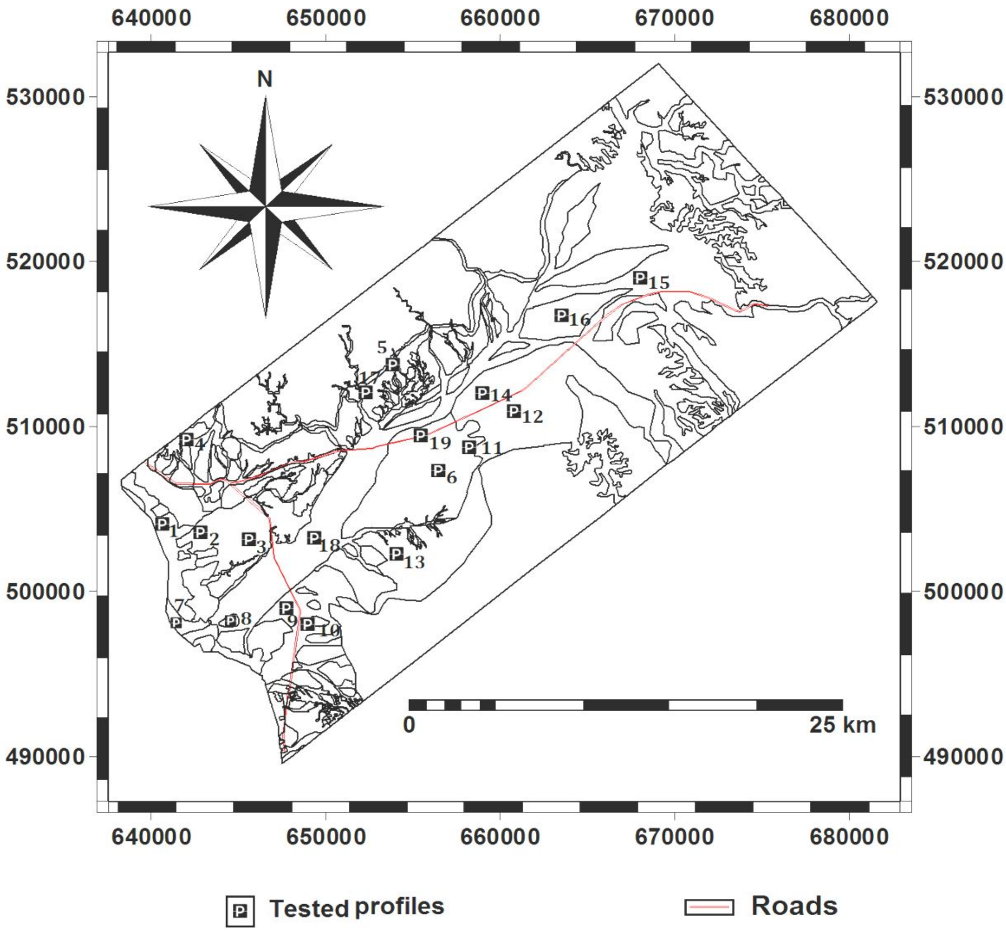

Figure 2. A location map of the studied soil profiles.

3. Coding Soil Database Attributes and Soil Map Generation

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

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

4. Land Capability Assessment.

California Storie index, Storie (1978) and revised Storie index, O'Geen *et al.,* (2008)., were used to judge the soil grade for intensive agriculture. The results were displayed as maps using "ILWIS"-GIS.

Results and Discussion

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 oxidation-reduction status of the soils or their layers. The yellow color dominates in most layers of the dry samples, whereas the dark yellowish brown was found in layers of relatively high content of clay.

No clay migration evidence was observed and the sandy loam texture was 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 they fulfill the requirements of calcic horizons, especially in the piedmont and valley landscapes. Few gypsum concretions, crystals and cementations are also recorded.

The field study revealed that the topographic features were generally gently undulating to gently sloping that surrounded by steep scarps in the boundary of the Plateau. The soils were generally deep as the effective soil depth was 150 cm or more in most cases except for some areas of shallow depth in the eastern parts of the studied areas of Wadi El-Assiuti, due to bedrocks at a depth of 50 120 cm. The dominated soil structure types were weak or moderate granular and medium sub- angular blocky while structurless single grains was dominating the sandy texture samples (Table, 2).

The parent materials of the soils of the study area is generally originated from calcareous sandstone deposits. Based on the USDA soil taxonomy Soil Survey Staff (2014a) most of the studied soil profiles are classified as Typic Haplocalcids and Typic Haplosalids (Table, 1).

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, revealed variations in the soil texture classes whether among the profiles or along the entire depths of each profile (Table 3).

Relatively high bulk density values, were recorded and ranged between1.34 and 1.69 g/cm^3 in the soil samples (Table 4). The coarse texture nature and the low organic matter contents, may contribute 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 (Table 4). The maximum value of 27.35 cm/hr was found in the surface layer of profile 7 that has a sand texture. However, the minimum value of 4.74 cm/hr was recorded in the subsurface and surface layers of profiles6 and 17, respectively that show a sandy loam texture. The average values of available water of the soil samples varied from 5.64 to 12.50% (Table 4). The minimum value was shown in the subsurface layer of profile 5 that has sand texture with total porosity of 36.12%, whereas the maximum value of 12.5% was in the deepest layer of profile 7 which shows a sandy loam texture with total porosity of 40.00%.

The calcium carbonate content ranged between 0.42 to 32.12% with a general trend to increase in the profile bottom reflecting the calcareous parent material nature of the studied soils (Table 5). Such variations may be due to differences in the lime content of the parent material.

The soils are characterized by low contents of organic matter that ranged between 0.02 and 0.73 % in a good agreement with the prevailing arid conditions. Most of the studied soil samples indicated a slightly alkaline soil reaction (pH) ranging between 7.91 to 8.48.

The cation exchange capacity of the studied soils varied between 3.11 and 8.72 cmol (+)/kg which was affected mainly by the dominant coarse texture classes (Table 5). Exchangeable sodium percentage values were relatively low and vary from 2.01 to 11.56% (Table 5). The occurrence of free calcium from gypsum and $CaCO_3$ may be contribute in the prevailed low ESP values.

The salinity level of most of studied soils was relatively high. The ECe values differed between 0.36 and 52.7 dS/m (Table 6). Soluble cations were dominated by sodium followed by calcium and magnesium and then, potassium. For soluble anions, chlorides were the dominant ones in most of the studied soil samples followed by sulphates and then, bicarbonates, indicating that NaCl was the dominant salt (Table 6).

Total nitrogen, phosphorus and potassium status shows a relatively low fertility potential for the investigated soils (Table 7). The soils samples seem to be extremely poor in the total N that decreased with depth. Low values of available P were present in most locations and ranged between 2.29 and 10.79 mg/kg. Available K values varied from 11.97 to 195.32 mg/kg.

The hot climate desert zone, as well as the absence of natural vegetation and the directly inhibitive effective of the soil salinity stress are the main factors affecting the reduction in the soil organic component. A reversible trend was observed for the soil $CaCO_3$ content, which it was generally found irrelatively high contents in some localities mostly due to the precipitation of calcium bicarbonate Ca $(HCO_3)_2$ as a secondary $CaCO_3$.

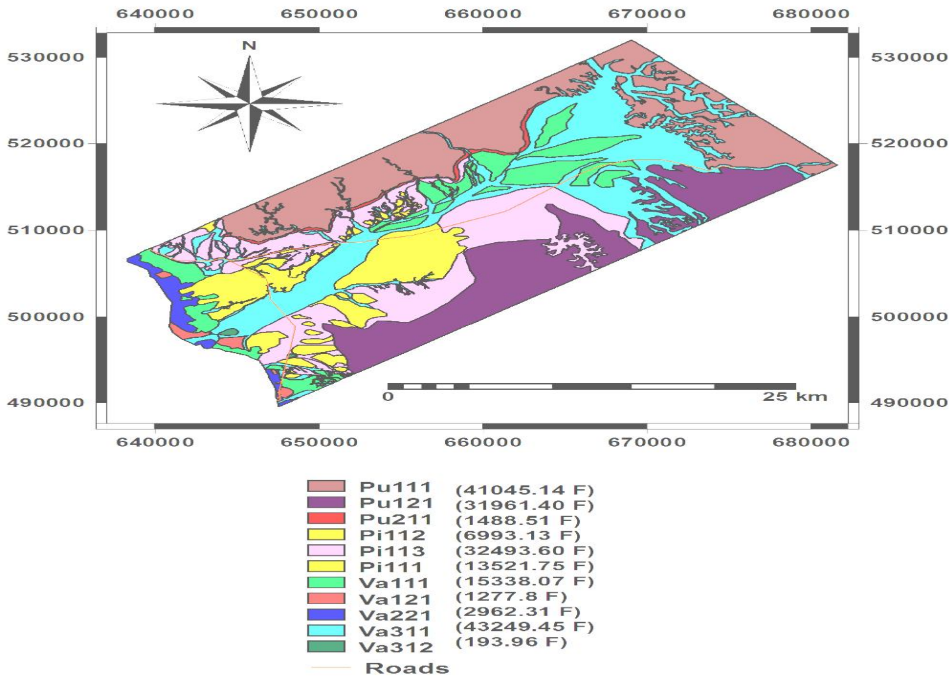

Figure 3. The geopedological map of the study area.

Table 1. The geopedlogical map legend

Landscape	Relief	Lithology	Land Form	Map Symbol	Area (Feddan)	Modal Profile	Soil Classification
Plateau (Pu)	Mesa	Marine limestone	Dissected Mesa	Pu111	41045.14	X	Rockout crop
		Chalky limestone	Dissected Mesa	Pu121	31961.40	X	Rockout crop
	Escarpment	Limestone	Scarps	Pu211	1488.51	X	Rockout crop
Piedmont (Pi)	Hills	Calcareous sandstone	Slope facet complex	Pi111	13521.75	P6	Typic Haplocalcids
			Summit & shoulders	Pi112	6993.13	X	Rockout crop
			Back slope	Pi113	32493.60	P12	Typic Haplocalcids
Valley (Va)	High Ter-races	Fanglomerate	Tread	Va111	15338.07	P16	Typic Haplocalcids
	Low Ter-races	Alluvial PreNile	Tread	Va121	1277.87	P7	Typic Haplocalcids
		Alluvial NeoNile	Tread	Va221	2962.31	P1	Typic Haplosalids
	Wadi bot-tom	Alluvial	Swales	Va311	43249.45	P18	Typic Haplocalcids
			Depression	Va312	193.96	P8	Typic Haplocalcids

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

Mapping unit symbol	Profile No.	Depth (cm)	Horizon	Soil color			Texture	Consistence	Soil structure			Horizon Boundary
				Hue	Dry	Moist			Grade	Size	Type	
Pi111	P6*	0- 45	C1	10 YR	7/4	6/4	ls	sh	1	f	pl	as
		45- 100	C2	10 YR	7/4	6/4	sl	vh	1	f	mas	--
	P2	0- 22	C1	10 YR	8/4	5/6	sl	sh	1	f	pl	as
		22- 36	C2	10 YR	8/4	5/6	sl	sh	1	f	sbk	as
		36- 72	C3	10 YR	6/4	5/4	sl	h	1	f	sbk	as
		72 - 150	C4	10 YR	5/3	4/4	sl	vh	2	m	mas	--
	P3	0- 55	C1	10 YR	8/4	5/6	sl	sh	1	f	sbk	as
		55-85	C2	7.5 YR	5/8	4/4	ls	h	1	m	sbk	as
		85- 90	C3	7.5 YR	5/8	4/4	sl	vh	2	m	pl	as
		90- 180	C4	7.5 YR	5/8	4/4	sl	vh	2	m	pl	--
	P11	0- 15	C1	10 YR	7/4	5/6	s	sh	1	f	pl	as
		15- 60	C2	10 YR	7/4	5/6	s	sh	1	f	st	as
		60- 110	C3	10 YR	7/4	5/6	s	h	1	f	st	--
	P19	0- 10	C1	7.5 YR	6/4	5/6	ls	sh	1	f	abk	aw
		10- 60	C2	7.5 YR	6/4	5/6	ls	sh	1	f	sbk	as
		60- 125	C3	7.5 YR	6/4	5/6	ls	h	2	f	mas	as
		125- 180	C4	7.5 YR	6/4	5/6	ls	h	2	m	sbk	--

Texture	***Structure*** Grade	Size	Type	***Consistence***	***Boundary***
sl = Sandy loam	1 = Weak	f = Fine	mas = Massive	sh =Slightly hard	as= Abrupt smooth
ls = Loamy sand	2 = Moderate	m = Medium	sbk=Subangular blocky	h = hard	aw= Abrupt wavy
s = Sand			abk = Angular blocky	vh = Very hard	w = Wavy
			pl = Platy		
			prs= Prismatic		

*=The modal profile for each mapping unit.

Table 2. (Continued)The main morphological aspects of the studied soil profiles.

Mapping unit symbol	Profile No.	Depth (cm)	Horizon	Soil color			Texture	Consistence	Soil structure			Horizon boundary
				Hue	Dry	Moist			Grade	Size	Type	
Pi113	P12*	0- 40	C1	10 YR	7/4	5/6	s	sh	1	f	pl	as
		40- 120	C2	10 YR	7/4	5/6	s	sh	1	f	st	as
		120-150	C3	10 YR	7/4	5/6	s	h	1	f	st	--
	P4	0- 15	C1	10 YR	5/3	4/4	sl	sh	1	f	abk	w
		15- 30	C2	10 YR	5/6	4/4	sl	h	1	f	sbk	w
		30- 100	C3	10 YR	5/6	4/4	sl	vh	1	m	mas	--
	P5	0 - 10	C1	10 YR	7/4	6/4	sl	sh	1	f	sbk	aw
		10-30	C2	10 YR	7/4	6/4	s	h	1	f	st	aw
		30- 150	C3	10 YR	7/4	6/4	ls	vh	1	f	sbk	--
	P9	0-20	C1	10 YR	7/4	5/4	s	sh	1	f	pl	as
		20- 40	C2	10 YR	7/4	5/6	s	sh	1	f	pl	as
		40- 100	C3	10 YR	7/4	5/6	s	h	1	f	st	as
		100- 130	C4	10 YR	7/4	5/6	s	h	1	f	st	as
		130- 150	C5	10 YR	7/4	5/6	s	vh	2	f	st	--
	P10	0- 20	C1	10 YR	7/4	5/6	s	sh	1	f	st	as
		20- 40	C2	7.5 YR	6/6	5/6	ls	sh	1	f	pl	as
		40- 65	C3	7.5 YR	6/6	5/6	ls	h	2	f	mas	as
		65- 180	C4	7.5 YR	6/6	5/6	ls	vh	2	f	st	--
	P13	0- 15	C1	10 YR	7/4	5/6	ls	sh	1	f	sbk	as
		15- 30	C2	10 YR	7/4	5/6	ls	h	2	m	sbk	as
		30- 100	C3	10 YR	7/4	5/6	ls	vh	2	m	mas	--
	P14	0- 10	C1	7.5 YR	7/4	6/4	s	sh	1	f	sbk	as
		10- 30	C2	7.5 YR	7/4	6/4	s	sh	1	f	sbk	as
		30- 100	C3	7.5 YR	7/4	6/4	s	h	1	f	st	--
	P17	0- 10	C1	7.5 YR	6/4	4/4	sl	sh	1	f	abk	as
		10- 30	C2	7.5 YR	6/4	4/4	ls	h	2	m	sbk	as
		30- 70	C3	7.5 YR	8/4	6/4	ls	vh	2	m	sbk	aw
		70- 150	C4	10 YR	6/3	4/4	s	vh	2	m	st	--

*=The modal profile for each mapping unit.

Texture
sl = Sandy loam
ls = Loamy sand
s = Sand

Structure
Grade
1 = Weak
2 = Moderate

Size
f = Fine
m = Medium

Type
Mas = Massive
Sbk = Subangular blocky
Abk = Angular blocky
pl = Platy
prs= Prismatic

Consistence
sh = Slightly hard
H = hard
vh = Very hard

Boundary
as= Abrupt smooth
aw= Abrupt wavy
w = Wavy

Table 2. (Continued)The main morphological aspects of the studied soil profiles.

Mapping unit symbol	Profile No.	Depth (cm)	Horizon	Soil color			Texture	Consistence	Soil structure			Horizon boundary
				Hue	Dry	Moist			Grade	Size	Type	
Va111	P16*	0- 20	C1	7.5 YR	8/4	6/4	s	sh	1	f	sbk	aw
		20- 40	C2	7.5 YR	8/4	6/4	s	sh	1	f	pl	aw
		40- 60	C3	7.5 YR	8/4	6/4	sl	h	1	f	pl	aw
		60- 80	C4	7.5 YR	6/8	5/6	s	h	1	f	sbk	aw
		80-100	C5	7.5 YR	8/2	6/2	s	h	2	m	sbk	aw
		100-120	C6	7.5 YR	8/2	6/2	s	vh	2	m	st	aw
		120-150	C7	7.5 YR	8/2	6/2	s	vh	2	m	st	--
Va121	P7*	0- 15	C1	10 YR	6/4	5/3	s	sh	1	f	prs	w
		15- 45	C2	10 YR	6/3	5/3	ls	h	1	f	prs	w
		45- 90	C3	10 YR	6/3	5/3	sl	vh	2	m	prs	w
		90-150	C4	10 YR	6/3	5/6	sl	vh	2	m	mas	--
Va221	P1*	0- 45	C1	10 YR	6/3	5/2	sl	sh	1	f	pl	as
		45- 50	C2	10 YR	5/6	4/4	sl	sh	1	f	pl	as
		50- 80	C3	10 YR	5/6	4/2	ls	h	1	f	sbk	as
		80-150	C4	10 YR	7/3	6/2	s	vh	1	f	st	--
Va311	P18*	0- 20	C1	10 YR	7/2	5/2	ls	sh	1	f	pl	aw
		20- 40	C2	10 YR	7/3	6/3	ls	Sh	1	f	pl	aw
		40- 60	C3	10 YR	8/4	6/4	s	h	1	f	st	aw
		60-100	C4	10 YR	8/4	6/4	s	h	1	f	st	--
	P15	0- 25	C1	7.5 YR	8/4	6/4	s	sh	1	f	sbk	as
		25- 35	C2	7.5 YR	8/4	6/4	s	sh	1	f	st	as
		35- 90	C3	7.5 YR	8/4	6/4	s	h	2	m	pl	as
		90-150	C4	7.5 YR	8/4	6/4	s	vh	2	m	st	--
Va312	P8*	0- 25	C1	10 YR	6/4	5/6	sl	sh	1	f	sbk	as
		25- 35	C2	10 YR	6/4	5/6	ls	h	1	m	sbk	as
		35- 80	C3	10 YR	6/4	5/6	ls	vh	2	m	sbk	as
		80-150	C4	10 YR	5/6	4/4	ls	vh	2	m	mas	--

*=The modal profile for each mapping unit.

Texture
sl = Sandy loam
ls = Loamy sand
s = Sand

Structure
Grade: 1 = Weak; 2 = Moderate; 3 = Strong
Size: f = Fine; m = Medium
Type: mas = Massive; sbk=Subangular blocky; abk = Angular blocky; pl = Platy; prs= Prismatic

Consistence
sh =Slightly hard
h = hard
vh = Very hard

Boundary
as= Abrupt smooth
aw= Abrupt wavy
w = Wavy

Table 3. The particle-size distribution of the studied soil profiles.

Mapping unit symbol	Profile No.	Depth (cm)	Particle size distribution (%)				Textural grade
			Coarse sand	Fine sand	Silt	Clay	
Pi111	P6*	0- 45	58.62	16.54	20.19	4.65	Loamy sand
		45- 100	59.29	11.00	25.45	4.26	Sandy loam
	P2	0- 22	70.42	4.19	17.70	7.69	Sandy loam
		22- 36	69.56	3.41	23.81	3.22	Sandy loam
		36- 72	61.16	7.58	24.83	6.43	Sandy loam
		72 - 150	71.76	5.02	16.41	6.81	Sandy loam
	P3	0- 55	73.20	4.95	12.82	9.03	Sandy loam
		55-85	70.97	6.66	14.79	7.58	Loamy sand
		85- 90	68.14	5.67	18.93	7.26	Sandy loam
		90- 180	67.12	6.96	18.76	7.16	Sandy loam
	P11	0- 15	87.68	5.66	3.72	2.94	Sand
		15- 60	92.22	3.23	1.76	2.79	Sand
		60- 110	83.69	4.94	7.87	3.50	Sand
	P19	0- 10	63.82	3.58	23.74	8.86	Loamy sand
		10- 60	60.59	2.79	28.39	8.23	Loamy sand
		60- 125	65.42	2.67	23.71	8.20	Loamy sand
		125- 180	62.76	2.79	26.04	8.41	Loamy sand
Pi113	P12*	0- 40	88.22	2.18	6.61	2.99	Sand
		40- 120	93.90	0.46	2.72	2.92	Sand
		120-150	94.44	0.57	1.96	3.03	Sand
	P4	0- 15	68.45	7.11	16.26	8.18	Sandy loam
		15- 30	67.78	6.63	18.03	7.56	Sandy loam
		30- 100	67.30	5.35	20.57	6.78	Sandy loam
	P5	0 - 10	52.07	12.37	26.38	8.73	Sandy loam
		10-30	82.40	5.36	9.21	3.03	Sand
		30- 150	73.27	5.15	16.97	4.61	Loamy sand
	P9	0-20	79.05	4.86	11.94	4.15	Loamy sand
		20- 40	82.56	2.85	6.98	7.61	Loamy sand
		40- 100	88.66	2.38	4.71	4.25	Sand
		100- 130	86.90	4.73	4.99	3.38	Sand
		130- 150	85.79	3.67	5.51	5.03	Sand
	P10	0- 20	80.24	6.68	10.12	2.96	Sand
		20- 40	83.75	2.46	5.51	8.28	Loamy sand
		40- 65	84.67	1.81	8.69	6.83	Loamy sand
		65- 180	74.15	2.37	11.63	11.85	Sandy loam
	P13	0- 15	72.30	5.10	16.30	6.30	Loamy sand
		15- 30	77.23	2.62	18.73	1.42	Loamy sand
		30- 100	83.47	2.13	12.83	1.57	Loamy sand

*=The modal profile for each mapping unit.

Table 3. (Continued) The particle-size distribution of the studied soil profiles.

Mapping unit symbol	Profile No.	Depth (cm)	Particle size distribution (%)				Textural grade
			Coarse sand	Fine sand	Silt	Clay	
Pi113	P14	0- 10	86.20	2.67	5.44	5.69	Sand
		10- 30	87.75	1.09	6.31	4.85	Sand
		30- 100	92.45	1.14	2.97	3.44	Sand
	P17	0- 10	73.10	2.20	16.80	7.90	Sandy loam
		10- 30	76.62	2.79	13.04	7.55	Loamy sand
		30- 70	73.30	2.52	20.37	3.81	Loamy sand
		70- 150	84.91	2.53	8.97	3.59	Sand
Va111	P16*	0- 20	90.50	0.55	2.69	6.26	Sand
		20- 40	92.70	1.53	0.21	5.56	Sand
		40- 60	70.83	3.48	18.11	7.58	Sandy loam
		60- 80	86.85	1.76	4.98	6.41	Sand
		80- 100	95.00	0.41	1.58	3.01	Sand
		100- 120	95.42	0.44	1.52	2.62	Sand
		120- 150	95.43	0.39	1.08	3.10	Sand
Va121	P7*	0- 15	83.18	4.27	9.06	3.49	Sand
		15- 45	79.04	5.41	10.65	4.90	Loamy sand
		45- 90	68.85	6.98	16.18	7.99	Sandy loam
		80- 150	73.34	4.61	12.89	9.16	Sandy loam
Va221	P1*	0- 45	40.33	11.92	38.41	9.34	Sandy loam
		45- 50	61.95	6.75	25.04	6.26	Sandy loam
		50- 80	84.39	1.93	4.60	9.08	Loamy sand
		90- 150	88.41	1.17	2.19	8.23	Sand
Va311	P18*	0- 20	85.83	1.98	6.21	5.98	Loamy sand
		20- 40	77.03	8.72	10.01	4.24	Loamy sand
		40- 60	93.28	1.42	2.20	3.10	Sand
		60- 100	94.98	0.30	1.72	3.00	Sand
	P15	0- 25	92.56	2.03	1.81	3.60	Sand
		25- 35	91.71	2.19	2.92	3.18	Sand
		35- 90	93.06	0.56	3.25	3.13	Sand
		90- 150	93.79	1.32	1.70	3.19	Sand
Va312	P8*	0- 25	68.55	7.56	14.41	9.48	Sandy loam
		25- 35	75.91	6.65	14.53	2.91	Loamy sand
		35- 80	70.77	8.26	18.50	2.47	Loamy sand
		80 - 150	80.55	5.62	11.42	2.41	Loamy sand

*=The modal profile for each mapping unit.

Table 4. Some physical properties of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	Bulk density (g/cm3)	Hydraulic conductivity (cm/h)	Soil moisture content(%)			Total porosity (%)
					Field capacity	Wilting point	Available water	
Pi111	P6*	0- 45	1.55	13.67	15.96	7.05	8.91	38.00
		45- 100	1.52	4.74	16.78	7.01	9.77	40.63
	P2	0- 22	1.63	6.62	16.22	6.85	9.37	34.80
		22- 36	1.59	7.19	16.33	6.73	9.60	39.54
		36- 72	1.54	6.79	15.71	6.24	9.47	38.40
		72 - 150	1.41	9.43	16.37	7.59	8.78	44.27
	P3	0- 55	1.52	7.42	16.72	6.85	9.37	40.63
		55-85	1.55	10.55	14.97	6.73	9.60	38.00
		85- 90	1.42	7.87	15.32	6.24	9.47	44.53
		90- 180	1.59	10.32	13.57	7.59	8.78	38.37
	P11	0- 15	1.62	16.72	8.61	2.91	5.70	38.40
		15- 60	1.64	16.34	8.54	2.86	5.68	37.64
		60- 110	1.60	16.36	8.72	2.94	5.78	39.16
	P19	0- 10	1.49	18.66	9.96	4.11	5.85	41.80
		10- 60	1.49	14.41	14.99	5.89	9.10	41.57
		60- 125	1.53	12.10	18.04	7.83	10.21	39.76
		125- 180	1.52	12.23	16.76	7.40	9.36	39.92
Pi113	P12*	0- 40	1.63	18.39	11.08	4.11	6.97	38.02
		40- 120	1.59	17.54	11.51	3.99	7.52	39.54
		120-150	1.60	18.88	12.87	4.79	8.08	39.16
	P4	0- 15	1.51	11.57	12.27	4.84	7.43	39.60
		15- 30	1.37	7.35	16.12	5.63	10.49	45.20
		30- 100	1.47	6.88	17.78	5.92	11.86	42.58
	P5	0 - 10	1.53	6.71	19.01	6.85	12.16	37.55
		10-30	1.68	16.24	8.52	2.88	5.64	36.12
		30- 150	1.52	14.99	14.87	7.21	7.66	39.92
	P9	0-20	1.46	13.16	14.87	6.16	8.71	44.49
		20- 40	1.52	16.97	14.48	6.08	8.40	40.63
		40- 100	1.51	18.51	11.56	4.51	7.05	42.59
		100- 130	1.56	14.35	13.35	5.45	7.90	37.60
		130- 150	1.61	18.11	12.87	5.02	7.85	37.60
	P10	0- 20	1.56	16.38	8.69	3.01	5.68	39.06
		20- 40	1.56	8.84	14.96	5.15	9.81	40.00
		40- 65	1.63	9.72	15.24	5.22	10.02	38.02
		65- 180	1.44	10.17	18.52	8.01	10.51	41.22
	P13	0- 15	1.50	12.05	18.07	7.87	10.20	41.18
		15- 30	1.52	14.14	15.10	5.80	9.30	40.62
		30- 100	1.55	12.23	16.76	7.66	9.10	39.92
	P14	0- 10	1.64	16.24	8.55	2.91	5.64	37.64
		10- 30	1.60	16.35	8.72	2.94	5.78	39.85
		30- 100	1.62	17.94	11.87	4.80	7.07	38.40
	P17	0- 10	1.67	4.74	20.14	8.08	12.06	35.52
		10- 30	1.54	16.96	14.57	6.04	8.53	40.31
		30- 70	1.57	8.78	15.96	7.09	8.87	39.38
		70- 150	1.55	17.56	11.59	4.62	6.97	38.25

*=The modal profile for each mapping unit.

Table 4. (Continued)Some physical properties of the studied soils

Mapping unit symbol	Profile No.	Depth (cm)	Bulk density (g/cm3)	Hydraulic conductivity (cm/h)	Soil moisture content (%)			Total porosity (%)
					Field capacity	Wilting point	Available water	
Va111	P16*	0- 20	1.61	16.24	8.67	2.91	5.76	39.25
		20- 40	1.55	17.91	10.99	4.38	6.61	41.51
		40- 60	1.49	8.72	18.52	8.36	10.16	40.64
		60- 80	1.53	17.55	11.36	4.46	6.90	40.70
		80- 100	1.61	19.76	12.83	4.94	7.89	38.08
		100- 120	1.62	18.64	11.96	4.87	7.09	38.40
		120- 150	1.62	20.11	9.50	3.04	6.46	38.87
Va121	P7*	0- 15	1.63	27.35	10.13	4.30	5.83	33.47
		15- 45	1.39	14.56	11.62	4.77	6.85	43.27
		45- 90	1.47	13.54	18.52	8.26	10.26	40.00
		80- 150	1.47	9.64	20.78	8.28	12.50	40.00
Va221	P1*	0- 45	1.34	12.24	16.38	9.73	6.65	46.61
		45- 50	1.49	8.69	13.08	4.51	8.57	40.40
		50- 80	1.54	5.85	15.31	6.56	8.75	40.31
		90- 150	1.61	16.35	8.72	2.94	5.78	37.60
Va311	P18*	0- 20	1.60	13.07	14.43	6.08	8.35	38.93
		20- 40	1.62	12.56	10.67	4.71	5.96	37.45
		40- 60	1.62	12.25	8.94	3.11	5.83	38.17
		60- 100	1.69	18.19	12.87	4.99	7.88	35.50
	P15	0- 25	1.63	18.41	8.69	2.87	5.82	35.57
		25- 35	1.69	17.92	8.56	2.85	5.71	34.50
		35- 90	1.64	18.76	9.13	3.32	5.81	38.11
		90- 150	1.62	17.51	10.89	4.51	6.38	38.40
Va312	P8*	0- 25	1.52	14.32	16.44	7.12	9.32	41.09
		25- 35	1.58	11.51	18.62	7.89	10.73	35.51
		35- 80	1.51	10.82	19.02	7.98	11.04	41.02
		80 - 150	1.51	11.14	18.10	7.89	10.21	38.37

*=The modal profile for each mapping unit.

Table 5. Some chemical properties of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	pH (1:1)	$CaCO_3$ content (%)	Organic matter (%)	Gypsum content (%)	Cation exchange capacity (cmol (+)/kg)	Exchangeable Na (%)
Pi111	P6*	0- 45	8.46	27.05	0.25	0.45	4.72	4.03
		45- 100	8.48	28.74	0.17	0.82	5.22	4.41
	P2	0- 22	8.22	9.30	0.20	2.04	7.14	4.22
		22- 36	8.14	8.88	0.17	2.31	6.11	4.62
		36- 72	8.11	5.24	0.16	1.31	5.22	5.56
		72 - 150	8.34	4.31	0.11	0.09	6.72	6.99
	P3	0- 55	8.15	16.57	0.19	1.99	6.05	7.16
		55-85	7.99	16.90	0.14	0.41	5.97	4.34
		85- 90	7.91	17.75	0.07	0.41	6.62	5.48
		90- 180	8.44	16.90	0.06	0.53	6.56	5.40
	P11	0- 15	8.45	12.26	0.19	--	4.73	2.65
		15- 60	8.43	18.09	0.12	0.75	4.49	2.56
		60- 110	8.46	16.90	0.11	1.82	4.45	2.41
	P19	0- 10	8.11	28.18	0.21	2.30	6.09	10.02
		10- 60	7.94	32.12	0.14	1.89	4.64	5.66
		60- 125	8.13	23.67	0.05	2.21	5.29	10.40
		125- 180	7.95	27.89	0.04	2.84	6.23	9.47
Pi113	P12*	0- 40	8.46	17.24	0.18	1.82	4.81	2.61
		40- 120	8.07	16.48	0.14	1.04	4.33	2.01
		120-150	8.30	14.71	0.11	0.77	4.41	2.09
	P4	0- 15	8.35	11.83	0.18	2.67	6.72	4.20
		15- 30	8.14	8.88	014	2.67	5.66	9.19
		30- 100	8.21	11.83	0.05	1.45	6.75	8.52
	P5	0 - 10	8.32	25.36	0.22	0.63	6.81	4.30
		10-30	8.43	27.05	0.18	2.06	4.75	2.63
		30- 150	8.45	30.43	0.12	0.11	4.91	4.28
	P9	0-20	8.37	15.55	0.16	1.33	4.99	5.01
		20- 40	8.32	16.82	0.14	1.96	6.01	5.59
		40- 100	8.36	16.48	0.15	0.26	5.14	2.67
		100- 130	8.47	14.62	0.14	1.21	4.60	2.78
		130- 150	8.41	18.17	0.12	0.14	4.25	2.94
	P10	0- 20	8.42	21.13	0.18	1.65	5.06	2.88
		20- 40	8.44	17.75	0.13	0.33	6.41	5.44
		40- 65	8.41	19.44	0.11	0.36	6.26	5.40
		65- 180	8.35	20.71	0.07	1.33	8.62	6.58
	P13	0- 15	8.37	16.74	0.22	1.75	6.34	4.84
		15- 30	8.05	18.17	0.19	2.87	6.90	6.74
		30- 100	8.01	13.10	0.15	2.23	6.23	6.38

*=The modal profile for each mapping unit.

Table 5.(Continued) Some chemical properties of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	pH (1:1)	$CaCO_3$ content (%)	Organic matter (%)	Gypsum content (%)	Cation exchange capacity (cmol (+)/kg)	Exchangeable Na (%)
Pi113	P14	0- 10	8.09	16.48	0.17	0.02	3.91	2.81
		10- 30	8.15	17.75	0.10	1.87	3.99	2.46
		30- 100	8.02	17.75	0.08	1.58	4.01	2.11
	P17	0- 10	8.34	12.68	0.18	2.43	7.27	5.31
		10- 30	8.24	12.26	0.11	2.31	8.02	6.01
		30- 70	8.34	14.24	0.09	2.06	6.43	9.82
		70- 150	8.32	8.45	0.07	1.40	4.12	2.51
Va111	P16*	0- 20	8.11	23.67	0.08	--	3.11	2.14
		20- 40	8.17	21.13	0.06	--	3.07	2.01
		40- 60	8.19	29.58	0.04	--	8.17	4.32
		60- 80	8.11	13.10	0.03	--	4.11	2.12
		80- 100	8.11	11.58	0.03	--	4.89	2.16
		100- 120	8.21	8.88	0.02	--	3.11	4.30
		120- 150	8.24	10.14	0.02	--	3.81	2.65
Va121	P7*	0- 15	8.46	15.21	0.24	0.94	4.89	2.17
		15- 45	8.41	19.44	0.15	0.72	4.99	4.41
		45- 90	8.09	22.82	0.08	--	8.18	8.92
		80- 150	8.41	22.82	0.06	--	8.11	6.55
Va221	P1*	0- 45	8.44	0.51	0.73	2.28	8.72	10.32
		45- 50	8.45	0.42	0.42	2.30	8.44	11.56
		50- 80	8.13	0.42	0.14	0.02	7.08	4.80
		90- 150	8.08	0.85	0.12	--	4.89	2.12
Va311	P18*	0- 20	8.39	19.44	0.27	--	4.61	5.86
		20- 40	8.41	26.20	0.19	--	4.52	5.31
		40- 60	8.36	17.75	0.15	--	4.36	3.05
		60- 100	8.13	16.23	0.07	--	4.21	2.75
	P15	0- 25	8.17	22.82	0.09	--	4.08	2.02
		25- 35	8.08	25.36	0.07	--	4.23	2.04
		35- 90	8.18	23.67	0.06	--	4.13	2.09
		90- 150	8.15	29.58	0.04	--	3.88	2.07
Va312	P8*	0- 25	8.23	17.33	0.28	1.40	8.05	5.79
		25- 35	8.19	17.33	0.22	1.14	6.06	5.46
		35- 80	8.24	16.90	0.21	1.35	6.40	5.47
		80 - 150	8.34	15.64	0.20	1.43	4.35	5.51

*=The modal profile for each mapping unit.

Table 6. Some chemical analysis of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	ECe (dS/m)	Soluble cations and anions (me/l)							
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
Pi111	P6*	0- 45	1.96	10.54	6.85	1.32	0.88	--	1.11	11.75	6.74
		45- 100	1.55	7.18	3.22	3.56	0.59	--	1.11	9.09	5.31
	P2	0- 22	4.65	28.99	10.54	14.70	2.32	--	1.11	37.41	7.91
		22- 36	5.33	36.89	10.54	13.70	2.17	--	1.67	36.19	11.44
		36- 72	3.13	17.92	5.80	13.17	0.71	--	1.11	10.11	12.08
		72 - 150	2.66	2.64	1.58	22.23	0.16	--	1.67	19.61	5.32
	P3	0- 55	12.0	26.35	12.65	78.18	2.02	--	1.67	101.35	12.18
		55-85	8.25	46.90	11.07	43.99	0.49	--	1.67	68.73	11.91
		85- 90	7.30	39.53	8.96	33.50	0.44	--	1.22	60.38	11.24
		90- 180	7.41	20.55	5.80	73.33	0.44	--	1.55	65.68	6.75
	P11	0- 15	0.83	2.64	1.22	3.61	0.83	--	1.33	4.79	2.18
		15- 60	1.82	14.76	1.58	1.18	0.66	--	1.22	13.71	3.14
		60- 110	7.19	9.53	3.18	48.32	0.88	--	1.11	62.85	7.94
	P19	0- 10	29.5	111.93	34.26	143.97	2.25	--	1.33	278.99	14.68
		10- 60	24.9	109.12	34.80	112.84	2.25	--	1.33	234.57	13.10
		60- 125	25.2	89.59	31.62	118.49	2.25	--	1.33	238.55	12.12
		125- 180	31.6	95.20	52.70	160.69	2.87	--	1.33	304.59	10.48
Pi113	P12*	0- 40	6.56	21.08	5.27	39.10	1.58	--	1.11	57.41	7.08
		40- 120	3.21	16.55	4.22	10.94	0.39	--	0.78	20.10	11.22
		120-150	1.77	10.81	5.54	1.89	0.09	--	1.33	8.79	7.58
	P4	0- 15	19.03	39.53	10.54	139.61	0.69	--	2.44	162.68	15.18
		15- 30	33.6	130.17	43.74	161.41	0.54	--	1.67	293.56	40.93
		30- 100	22.0	137.02	39.53	143.04	0.41	--	1.11	198.93	17.96
	P5	0 - 10	2.55	11.07	2.11	10.92	1.40	--	1.11	15.88	8.44
		10-30	3.12	22.67	6.85	1.08	0.66	--	0.67	21.75	7.78
		30- 150	3.68	23.72	7.91	4.90	0.83	--	1.11	28.28	7.41
	P9	0-20	9.84	34.26	15.81	67.93	2.37	--	1.22	89.95	7.23
		20- 40	8.06	42.16	13.18	44.01	2.25	--	1.22	72.29	7.18
		40- 100	3.83	15.27	11.62	19.64	1.77	--	1.22	28.11	4.58
		100- 130	4.92	13.45	8.18	25.12	1.90	--	1.22	43.28	5.42
		130- 150	4.52	15.81	5.27	23.85	0.98	--	1.22	38.63	5.35
	P10	0- 20	6.86	36.36	13.70	47.12	0.96	--	1.22	59.68	7.70
		20- 40	1.57	6.91	4.38	4.03	0.39	--	1.22	10.57	3.91
		40- 65	1.61	8.96	4.22	3.31	0.61	--	1.22	10.88	3.99
		65- 180	1.75	2.64	2.64	12.09	0.14	--	1.22	13.70	2.58
	P13	0- 15	3.43	16.45	8.35	9.04	2.07	--	1.33	23.05	9.92
		15- 30	7.97	20.84	3.38	54.25	2.25	--	1.11	66.33	12.47
		30- 100	8.35	22.16	5.81	51.28	2.25	--	1.33	71.33	10.84
	P14	0- 10	1.41	5.27	2.63	4.91	1.01	--	1.67	6.53	5.91
		10- 30	3.81	17.35	7.91	9.04	1.85	--	1.33	28.05	8.72
		30- 100	3.14	18.08	10.54	2.01	0.98	--	1.33	23.05	7.02

*=The modal profile for each mapping unit.

Table 6. (Continued) Some chemical analysis of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	ECe (dS/m)	Soluble cations and anions (me/l)							
				Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
Pi113	P17	0- 10	4.97	24.26	5.27	19.89	1.08	--	1.33	39.58	8.79
		10- 30	11.94	31.62	7.91	99.81	2.07	--	1.33	108.31	9.77
		30- 70	35.50	79.05	10.54	265.51	1.13	--	1.33	328.59	25.08
		70- 150	6.61	34.26	8.96	28.91	0.98	--	1.33	42.63	22.14
Va111	P16*	0- 20	0.66	2.22	1.28	2.63	0.49	--	1.22	4.35	1.03
		20- 40	0.56	2.64	1.27	1.83	0.19	--	1.22	3.39	1.17
		40- 60	0.62	1.58	1.11	3.09	0.19	--	1.33	3.35	1.52
		60- 80	0.52	1.58	1.11	2.01	0.14	--	1.33	3.35	0.98
		80- 100	0.44	1.58	1.69	1.06	0.07	--	1.33	2.39	0.72
		100- 120	0.36	1.05	1.16	1.37	0.09	--	0.78	2.39	0.47
		120- 150	0.43	1.64	1.64	1.09	0.12	--	1.33	2.39	0.62
Va121	P7*	0- 15	9.43	10.54	5.27	77.89	0.59	--	1.22	85.25	7.83
		15- 45	17.2	5.80	7.38	170.42	0.59	--	3.22	160.73	8.25
		45- 90	3.33	1.05	0.53	31.68	0.12	--	2.56	26.27	4.74
		80- 150	1.70	0.53	2.11	13.18	0.07	--	1.33	11.22	4.45
Va221	P1*	0- 45	52.7	22.13	20.03	487.32	2.03	--	1.67	442.51	72.83
		45- 50	37.8	12.12	11.59	354.22	0.79	--	1.67	312.92	59.44
		50- 80	10.0	2.64	0.53	96.20	0.68	--	1.55	88.75	8.75
		90- 150	9.05	1.58	1.05	90.20	0.61	--	1.67	77.91	10.92
Va311	P18*	0- 20	1.34	4.22	3.69	2.04	0.16	--	1.33	10.88	1.19
		20- 40	1.63	5.27	5.27	4.91	0.56	--	1.44	10.88	3.98
		40- 60	0.48	2.06	1.08	0.89	0.39	--	1.22	3.35	0.23
		60- 100	0.49	2.27	1.04	0.99	0.54	--	1.33	2.35	1.22
	P15	0- 25	0.43	2.11	1.16	1.52	0.29	--	0.78	2.35	1.17
		25- 35	0.57	2.03	1.04	2.05	0.31	--	0.78	3.21	1.31
		35- 90	0.65	2.64	2.64	1.44	0.16	--	1.33	3.35	1.82
		90- 150	0.39	1.05	1.11	1.67	0.07	--	1.33	2.35	0.98
Va312	P8*	0- 25	9.31	26.35	10.54	54.39	1.82	--	1.33	84.04	7.73
		25- 35	11.0	52.70	7.91	67.91	1.87	--	1.22	100.05	8.78
		35- 80	16.7	73.78	19.50	70.99	2.32	--	1.22	154.86	10.48
		80 - 150	11.0	63.24	28.46	66.68	1.97	--	1.22	98.31	10.74

*=The modal profile for each mapping unit.

Table 7. Total Nitrogen (N), available phosphorus (P) and available potassium (K) of the studied soils.

Mapping unit symbol	Profile No.	Depth (cm)	Total N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Pi111	P6*	0- 45	130	8.51	164.43
		45- 100	90	7.53	181.56
	P2	0- 22	100	3.11	162.69
		22- 36	90	3.17	156.92
		36- 72	80	3.30	177.90
		72 - 150	60	2.76	144.99
	P3	0- 55	100	10.05	108.89
		55-85	70	7.29	114.19
		85- 90	40	7.19	191.08
		90- 180	30	6.99	173.76
	P11	0- 15	100	9.22	148.74
		15- 60	70	8.44	152.49
		60- 110	60	6.85	127.57
	P19	0- 10	110	8.11	179.92
		10- 60	75	6.91	106.38
		60- 125	35	6.82	154.71
		125- 180	30	6.02	168.18
Pi113	P12*	0- 40	95	9.26	110.43
		40- 120	70	9.08	44.70
		120-150	55	8.31	23.48
	P4	0- 15	90	6.97	123.91
		15- 30	70	6.05	142.96
		30- 100	30	5.55	119.77
	P5	0 - 10	110	10.79	130.16
		10-30	90	7.67	131.32
		30- 150	60	5.92	133.44
	P9	0-20	80	8.29	104.81
		20- 40	70	7.48	178.19
		40- 100	80	6.80	143.06
		100- 130	70	4.45	194.84
		130- 150	60	3.96	118.33
	P10	0- 20	95	7.66	108.69
		20- 40	70	7.42	103.99
		40- 65	60	6.64	102.12
		65- 180	45	6.30	109.96
	P13	0- 15	120	5.44	114.67
		15- 30	105	5.28	81.94
		30- 100	80	4.83	73.86

*=The modal profile for each mapping unit.

Table 7. (Continued)Total Nitrogen (N), available phosphorus (P) and available potassium (K) of the studied soils.

Mapping unit Symbol	Profile No.	Depth (cm)	Total N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Pi113	P14	0- 10	95	7.83	129.78
		10- 30	60	6.79	114.28
		30- 100	40	6.56	94.75
	P17	0- 10	100	9.81	183.58
		10- 30	65	9.11	160.67
		30- 70	55	8.56	98.60
		70- 150	35	5.95	88.64
Va111	P16*	0- 20	45	9.69	42.77
		20- 40	40	7.51	36.997
		40- 60	25	6.94	31.17
		60- 80	25	5.52	27.52
		80- 100	20	4.45	21.60
		100- 120	20	4.17	11.97
		120- 150	20	2.29	17.75
Va121	P7*	0- 15	120	8.01	131.51
		15- 45	80	7.57	145.08
		45- 90	40	7.07	179.92
		80- 150	30	5.89	166.55
Va221	P1*	0- 45	370	6.55	148.84
		45- 50	210	4.32	109.38
		50- 80	70	8.76	112.45
		90- 150	60	7.03	143.06
Va311	P18*	0- 20	140	8.99	38.92
		20- 40	110	8.31	33.34
		40- 60	80	7.56	39.35
		60- 100	40	6.87	29.39
	P15	0- 25	55	9.71	63.95
		25- 35	40	8.60	77.42
		35- 90	35	7.86	55.45
		90- 150	30	7.60	41.97
Va312	P8*	0- 25	140	6.87	195.32
		25- 35	110	6.79	143.16
		35- 80	105	4.71	112.36
		80 - 150	100	3.13	183.48

*=The modal profile for each mapping unit.

3. Geopedlogical Characteristics of the Study Area

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

The geopedological map and its legend are shown in Figure, 3 and Table 1 respectively. The legend represents the hierarchical structure of the geo-pedomorphic units. Three landscapes are present in the study area, they are plateau, piedmont and Valley.

As it is shown in the legend, the modal profile for the unit is indicated through which all main soil characteristics are extracted for the map unit and stored within "ILWIS"-GISas a geographic database. Figure 4 shows the soil classification of the study area as an attribute map.

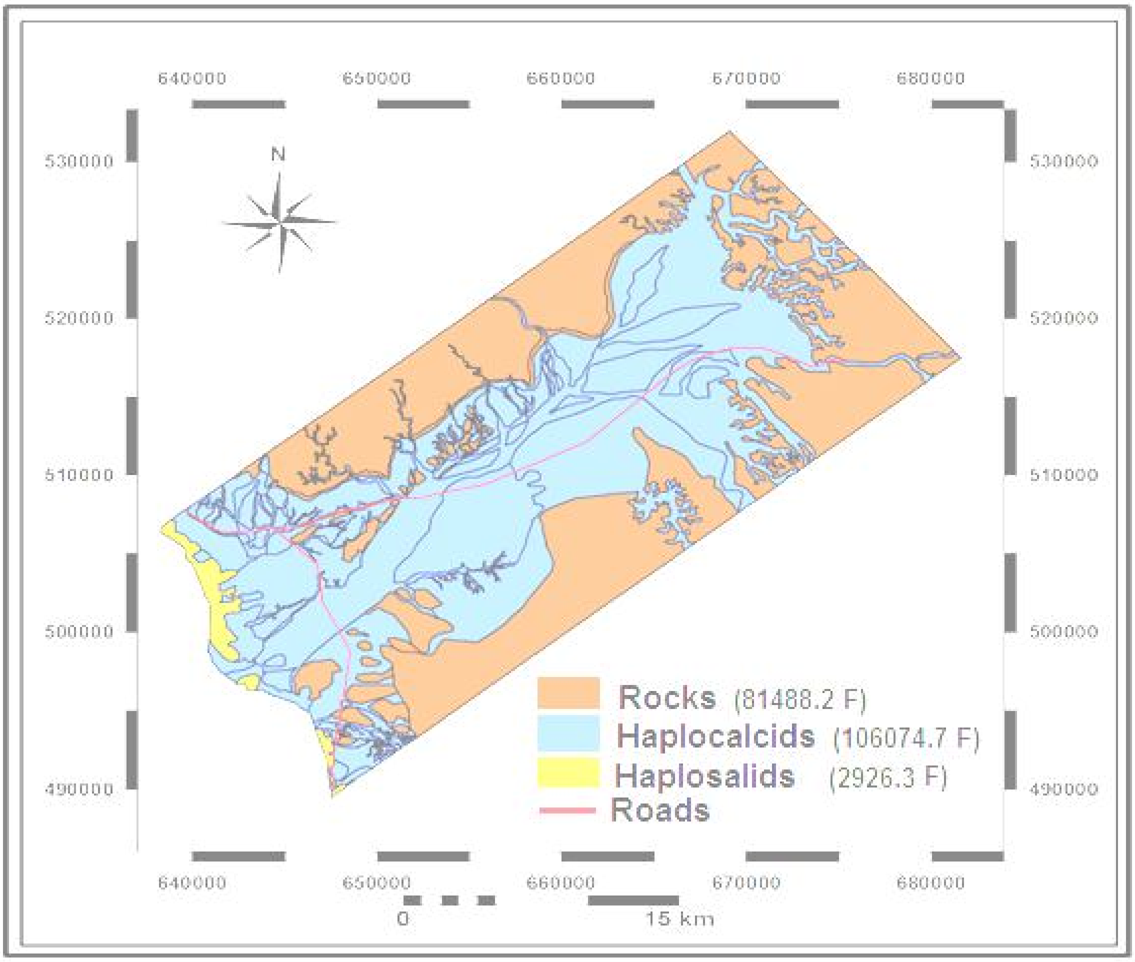

Figure 4. The soil classification map of the study area.

4. Land Capability Assessment.

The land capability assessment is an important step to determine the agriculture capability of the different soil mapping units in the study area. Table 8 shows the used soil characteristics and their limiting values for each capability class.

The quantitative estimation of environmental conditions and soil properties, such as A: (soil profile depth), B: (texture, permeability and available water), C: (slope), X: (drainage, CaCO3, gypsum, salinity and alkalinity) was used for the numerical land evaluation of California Storie index, Storie, (1978) and O'Geen *etal.* (2008).

The studied soil profiles were placed into classes according to their calculated capability indices. The calculated capability rating indices of the study area are presented in Table 9 and Figure 5. They show that the soils of the investigated area are placed in classes 2, 3 and 4 which are moderately capable, marginally capable and limited capable, respectively.

4.1 Current land capability:

After matching the land characteristics of the model profiles of each map unit with the land capability model, which was built in ILWIS software, the land capability class of each map unit was obtained (Figure 5). and the relative limitation(s) of each class is resulted (Table 9) and recorded as attribute table.

As it is found in Table 10 and Figure 5, the capability status of the study area is of "moderate ", to "marginal" and "limited" capabilities due to different limiting factors. High soil salinity, lime contents and shallow soil depth are mostly the main limiting factors over all the study area. Some of the recorded limiting factors are correctableas; high salinity contents. Limited practical corrections could be made also to moisture availability and cation capacity.

Table 8. Soil characteristics of the soil mapping units used in the capability model.

Soil characteristics	Class 1 (High capability)	Class 2 (Moderate capability)	Class 3 (Marginal capability)	Class 4 (Limited capability)	Class 4 (No capability)
Slope (%)	<2	2-5	5-8	8-16	> 16
Effective depth (cm)	≥120	90-120	60-90	25-60	<25
Drainage(1)	Class 4	Class 3.5	Class 2.6	Class 1	Class 0
Texture class(2)	L,SL,SCI,CL,SC	SiL,SiCL,SiC,Si, light C	F.S, C	S, G.S	Extremely G.Sand
Clay (%)	<35	35-50	50-60	60-80	>80
Permeability (cm/h)	2-6.25	0.5-2 6.25-12.5	0.25-0.5 12.5-25	0.12- 0.25 25-40	>40 <0.12
Available water(3) (mm)	≥120	80-120	80-60	60-30	<30
CEC (cmol(+)/kg)	≥30	15-30	10-15	5-10	<5
ECe (dSm^{-1})	<4	4-8	8-16	16-32	>32
ESP (%)	<15	15-20	20-30	30-40	>40
$CaCO_3$(%)	<10	10-20	20-40	40-50	>50

(1) According to FAO (2006).
(2) Texture class: L:Loam, SL:Sandy Loam, SCL: Sandy Clay Loam, SC: Sandy Clay, SiL:Silt Loam, SiCL: Silty Clay Loam, SiC: Silty Clay, Si: Silt, F.S.:Fine Sand, C: Clay, S:Sand, G.S.: Gravelly Sand
(3) Available water capacity depth till the effective depth up to 80 cm according to Rattan and Shukla (2004).

$$AMC = \frac{FC\% - WP\%}{100} * D_b * depth_{(mm)} \ldots\ldots (mm)$$

Table 9. Capability rating indices and classes of the study area.

Map unit	Model Profile	Current rating index (%)	Current capability class	Potential rating index (%)	Potential capability class	Area (feddan)
Pi111	P6	57.00	3	٥٧.00	3	13521.75
Pi113	P12	64.80	2	64.80	2	32493.60
Va111	P16	52.65	3	52.65	3	15338.07
Va121	P7	41.77	3	49.14	3	1277.87
Va221	P1	25.65	4	85.50	1	2962.31
Va311	P18	51.60	3	51.60	3	43249.45
Va312	P8	76.95	4	76.95	2	193.96

Table 10. Current capability verses potential capability of the study area

Capability class	Current area (feddan)	%	Potential area (feddan)	%
Class 1	--	--	2962.31	2.72
Class 2	32494.60	29.89	32687.55	29.98
Class 3	73387.14	67.21	73387.14	67.30
Class 4	3156.26	2.90	--	--
Class 5	--	--	--	--
Total area	109037.00	100.00	109037.00	100.00

The results show that 32493.6 feddans which constitute about 29.8% of the evaluated soils are considered moderate capable and about 73387.14 feddans that constitute about 67.30% have a marginal capability while 3156.26feddans accounting 2.90% of the total area have a limited capability for agriculture use. The main properties of the resulted capability classes could be summarized as following:

Class 2, moderately capable (C2)

The soils of this class (mapping unit Pi113) cover an area of 32494.60feddans. They are located adjacent to Assiut governorate and include the soils that have developed and can be slightly managed. The main limitations of these soils are lime contents, coarse texture,erosion risks and bioclimatic deficiency. These lands require a good and proper management. In this case, the soil productivity will be between moderately high and high for a fair range of crops.

Class 3, marginally capable (C3)

The soils of this class (mapping units Pi111, Va111, Va121 and Va311) cover an area of 73387.14feddans. They are considered suitable for irrigated agriculture and have minor limitations that reduce the choice of crops. In general, thesesoils have moderately deep soil profiles, with medium to coarse textural classes and possess moderately saline to saline classes.

This class includes the soils which have moderate development as well as moderate capability and moderate severe limitations that restrict the range of crops and require special conservation practices. The main limitations of these lands are the soil erosion risks and bioclimatic deficiency. Such lands have low to fair productivity of a range of crops and improvement practices can be feasible.

Class 4, limited capable (C4)

The soils that belong to this class (mapping units Va221 and Va312) cover an area of 3156.3 feddans which constitutes about 2.9%. They have moderate to serve limitations that reduce the choice of crops and /or require special conservation practices. The main limitations are profile depth, $CaCO_3$content and soil salinity. In general, these soils are highly saline, with shallow profiles. In other words, these lands have a marginal capability. The inherited severe limitations restrict their use for intensive arable culture. Therefore, these lands are recommended for forage crops and agro forestry systems.

4.2 Potential land capability:

The land capability of the study area is governed by different limiting factors. Some of these factors can be mitigated or improved by applying the appropriate soil management practices, resulting in improving the present land capability to be the potential land capability (Figure 6 and Table 10). These soil management practices include:

1- Leaching the soil salts using the surface irrigation.

2- Applying Organic fertilizers to improve CEC and nutrient availability.

3- Applying modern irrigation systems and reducing the irrigation periods to avoid salts accumulation and the formation of soil crust in the calcareous soils.

As seen from Table (10) the agricultural capability of the study area could be improved and there will be 2962.31 feddans that are highly capable, 32687.55 feddans that are moderately capable and 73387.14 feddans as marginally capable.

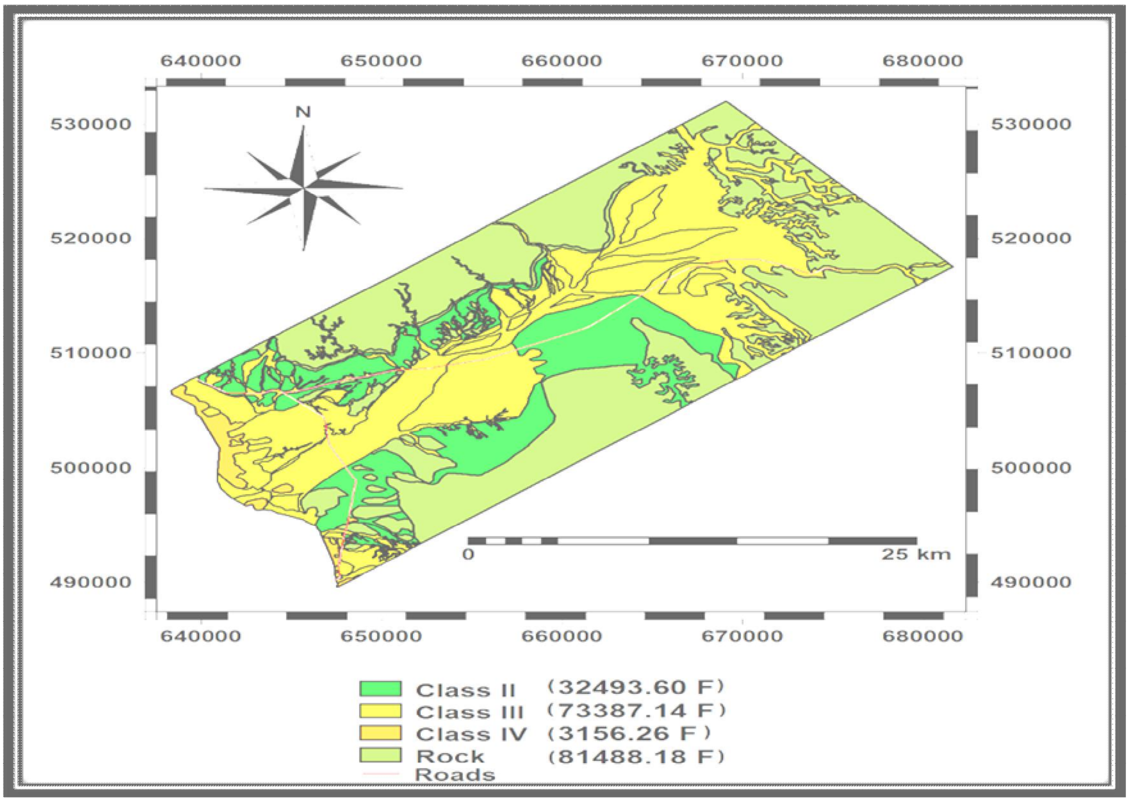

Figure 5. The current soil capability map of the studyarea

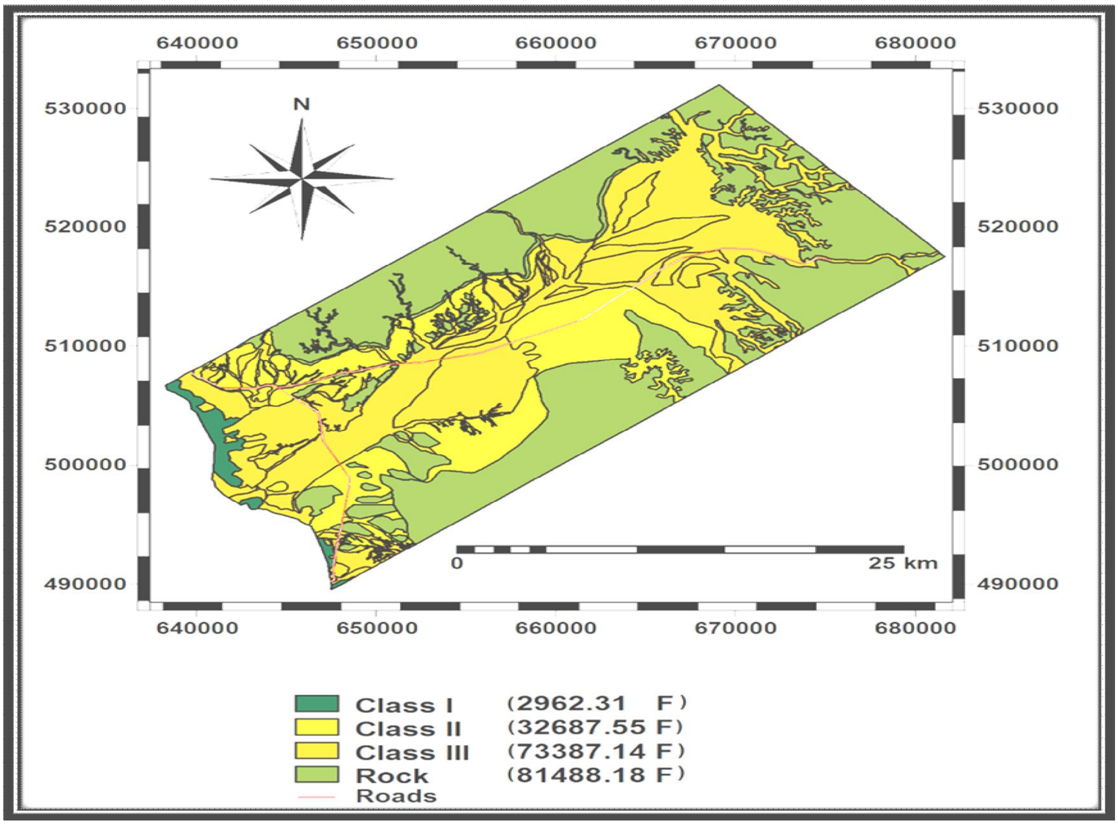

Figure 6. The potential soil capability map of the study area

Recommendations for the studied soils

After the results of the present work, the following conclusions and recommendations may be deduced:

1- The studied area possesses promising lands for agricultural expansion, as about 32493.60 fed are classified as moderately capable.; about 73387.14 fed are marginally capable and (about 3156.26 fed.) are considered with limited capability for agricultural development.

2- Moreover, by executing the capable agro management practices, the area could have (2962.31 fed.) of as high capability, (32687.55 fed.) with moderate capable and (73387.14 fed.) as marginal capability

3- The high soils salinity, $CaCO_3$ content, available moisture contents, low available nutrient and organic matter as well as effective soil depth represent the most limiting factors prevailing in the studied area. Therefore, it is recommended to execute leaching process for removing the excess soluble salts under an effective drainage system before establishing the agricultural utilization projects. Also, the problem of low retained moisture in the soil could be overcame through the application of well soil-water management through drip or sprinkler irrigation systems.

4- Crop selection of salinity tolerance should be taken into consideration, since the majority of the studied soils are suffering from salinity.

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استخدام الاستشعار عن بعد ونظم المعلومات الجغرافية في تقييم الجدارة الانتاجية لأراضي الوادي الأسيوطي، مصر.

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الملخص

أجريت هذه الدراسة على بعض أراضي منطقة وادي الأسيوطي في الصحراء الشرقية لمحافظة أسيوط. وتهدف الدراسة إلى اجراء حصر نصف تفصيلي لأراضي هذه المنطقة بالاستعانة بصور الأقمار الصناعية "لاندسات" وانظمة المعلومات الجغرافية وذلك لاجراء تقييم طبيعي لوحدات التربة الفيزيوجرافية لتقدير القدرة الانتاجية للاراضي التي تصلح للزراعة وذلك بالاستعانة ببرنامج ILWIS لأنظمة المعلومات الجغرافية. وقد تم أولا عمل تفسير مرئي لصور الأقمار الصناعية المتراكبة فوق نموذج الطبوغرافية الرقمي فى شكل ثلاثى الابعاد وذلك لانتاج خريطة التربة الجيوبيدولوجية والتي تم التحقق من وحداتها في الحقل، ثم تم تمثيل وحدات التربة الخرائطية بعدد ١٩ قطاع أرضي حيث تم عمل وصف كامل لها وتقدير الصفات الطبيعية والكيمائية لعينات التربة الممثلة لها ثم تخزين البيانات في قاعدة بيانات جغرافية. ولقد تم تقسيم الأراضي على اساس نظام التقسيم الأمريكيUSDA Soil Taxonomy حتى مستوى تحت المجموعة حيث وجدت مجموعات الأراضي الرئيسية بالمنطقة هي: Typic Haplocalcids and Typic Haplosalids.

تم اجراء تقييم للجدارة الانتاجية لأراضي المنطقة ثم تم اجراء تقييم طبيعي للأراضي الصالحة لاختبار مدى ملائماتها للزراعة المروية طبقا للاطار العام لدليل California Storie index(١٩٧٣) ، وتم الاستعانة ببرنامج ILWIS لنظم المعلومات الجغرافية لانتاج الخرائط . وقد أشارت النتائج المتحصل عليها الى ان المنطقة تشمل اراضي ذات قدرة انتاجية متوسطة بنسبة ٢٩,٩% و اراضي هامشية بنسبة ٦٧,٢% واراضي ضعيفة الانتاج بنسبة ٢,٩% من اجمالي مساحة المنطقة تحت الدراسة. وتعزى القدرة الانتاجية المنخفضة للمنطقة الى قوام الارض الخشن وعدم قدرتها على الاحتفاظ بالرطوبة ومحتواها العالي من الأملاح الذائبة وكربونات الكالسيوم والحالة الغذائية المنخفضة.

ولتحسين القدرة الانتاجية المستقبلية للأراضى الموجودة بالمنطقة فانه يوصى بتنفيذ اجراءات عملية يجب إجراؤها متعلقة بادارة التربة باضافة المادة العضوية والأسمدة الكيمائية لزيادة محتوى التربة من العناصر الغذائية وكذلك اتباع نظم الري الحديثة مع غسيل الأملاح وذلك لتحسين خصائص التربة التي تتسم بقابليتها للمعالجة وبالتالى يمكن الوصول الى الانتاجية الكامنة لهذه المنطقة لتصبح 2.72% عالية الجدارة بالنسبة لانتاجية التربة وحوالي 29.98% متوسطة الجدارة وحوالي 67.30% محدودة الانتاجية.

الكلمات الدالة: *القدرة الانتاجية للأراضي – القدرة الكامنة للأراضى – الاستشعار عن بعد – نظم المعلومات الجغرافية – ادارة الأراضي والمياه – أراضى الوادي الأسيوطي.*