



ISSN NO. 2320-5407

Journal homepage: <http://www.journalijar.com>

INTERNATIONAL JOURNAL
OF ADVANCED RESEARCH

RESEARCH ARTICLE

LAND SUITABILITY EVALUATION FOR CULTIVATION OF SOME SOILS IN WESTERN DESERT
OF EGYPT, EL-MINYA GOVERNORATE USING GIS AND REMOTE SENSING.

M. A. Azzam

Soil, Water and Environment Res. Inst., ARC, Giza, Egypt.

Manuscript Info**Manuscript History:**

Received: 14 December 2015
Final Accepted: 15 January 2016
Published Online: March 2016

Key words:

Physiographic mapping units,
Digital Elevation Model (DEM),
Soil Classification and Land
Capability Classification.

***Corresponding Author**

M.A. Azzam.

Abstract

The study area is selected to be one of the prospecting areas in the western desert according to some topographic and physical characters. It lies between latitudes $27^{\circ} 37'$ and $27^{\circ} 59'$ N & longitudes $30^{\circ} 15'$ to $30^{\circ} 36'$ E. and occupy about 337630 feddan. The studied area lies to the west of the River Nile in El-Minya Governorate. The present study aims at initiating a base geomorphologic map of the study area for soil mapping, classification and land evaluation for irrigated agriculture. To achieve this objective geological map, Landsat ETM⁺ image analysis (path 177-row 41), and Digital Elevation Model (DEM) supplemented by in situ data acquisition were used for delineating the main geomorphologic units. These units are low high terraces, medium high terraces, high terraces and rock land. Thirty five soil profiles representing the different physiographic units were exposed, morphologically described, classified according to Soil Taxonomy (USDA, 2014) and 101 soil samples were collected for lab analyses.

Two soil orders are identified in the study area i.e. *Aridisols*, which are dominated in the study area, and *Entisols*. These orders are differentiated into suborders, great groups, subgroups and families. The main soil sub-orders detected in the study area are *Gypsisols*, *Calcids* and *Orthents*. The study area is differentiated into the following families:

- *Typic Calcigypsisols*, sandy, mixed, hyperthermic.
- *Typic Calcigypsisols*, coarse loamy, mixed, hyperthermic.
- *Lithic Calcigypsisols*, sandy, mixed, hyperthermic .
- *Typic Haplocalcids*, coarse loamy over clayey, mixed, hyperthermic.
- *Typic Haplocalcids*, fine loamy, mixed, hyperthermic.
- *Typic Haplocalcids*, sandy, mixed, hyperthermic.
- *Typic Torriorthents*, sandy, mixed, hyperthermic.

The current suitability of the studied soil profiles was estimated by matching between the present land characteristics and their ratings outlined by Sys and Verhey (1978). Suitability indices and classification of the studied soils revealed that there are three suitability classes, i.e., moderately suitable, marginally suitable and not suitable. The soil limiting factors in the study area are soil texture, salinity and alkalinity, soil depth and gypsum content with slight to severe and very severe intensity.

Further land improvements are required to correct or reduce the severity of limitations existing in the studied area, such as: a) leaching of soils salinity, b) continuous application of organic manure to improve soil physico-chemical properties and fertility status, and c) application of modern irrigation system, i.e. drip and sprinkler. By applying the previous improvement practices according to Sys et al (1991), potential suitability of the studied soils could be raised to highly suitable, moderately suitable, marginally suitable and little areas of not suitable soil.

Copy Right, IJAR, 2016,. All rights reserved

Introduction:-

The main problem faced Egypt for many decades is over population against food production. This problem increased principally due to continuous decreasing in fertile land by urbanization. Through the last ten years 350,000 feddans of the high fertility land changed to different purposes except for cultivation (Ministry of Agriculture and land reclamation, 2013) . For that and for many reasons governorate exerts great efforts to recover the gap between population and food production by looking for new areas for cultivation. Desert reclamation for agricultural production is one of the priorities to compensate for the loss of agricultural land and to minimize food supply shortage in Egypt.

The study area is selected to be one of the prospecting areas in the western desert according to some topographic and physical characters .It lies between latitudes $27^{\circ} 37'$ and $27^{\circ} 59'$ N & longitudes $30^{\circ} 15'$ to $30^{\circ} 36'$ E and occupy about 337630 feddan.

The study area is considered one of the important areas of horizontal expansion in the Western desert. It is allocated in the western part of the River Nile, El Minya Governorate (Fig.1). The metrological records of El-Minya station **Egyptian Meteorological Authority (1996)** (means of 30 years, 1984 to 2014) show that:

- The total mean rainfall is 28.0 ml/ year.
- The mean relative humidity ranges from 33 % in May to 67% in Dec.
- Evaporation values range from 4.17 ml/ day in January to 12.2 ml/ day in June.
- Main monthly temperature ranges between 12.9°C in January and 30.2°C in Aug.

According to and the **American Soil Taxonomy (USDA, 1999)**, the soil temperature regime of the study area is hyperthermic and the soil moisture regime is torric.

Geologically, the study area is moderately elevated plateau with respect to River Nile and composed of mainly limestone covered with alluvial deposits of sands and gravels (Fig. 2). The Eocene rocks constitute the main outcrops, capped by poorly consolidated sand, gravel, and clay. The Pleistocene sediments is the main aquifer in the Delta and Nile valley, it composed of massive cross bedded fluvial sand with gravel and clay sediments. The overlapping between the Pleistocene and the Eocene sediments at the eastern and western borders of the River Nile was established.

The fundamental principle of land evaluation is to estimate the potential of a land for different productive uses, such as farming, livestock production, or forestry together with uses that provide services or other benefits, such as water catchment, recreation, tourism and wildlife conservation (Dent and Young, 1981). Consequently, land evaluation is a tool, for strategic land use planning. A specific agricultural use and management system on land that is most suitable according to agro-ecological potentialities and limitations is the best way to achieve sustainability (FAO, 1978).

The present study aims at soil mapping achievement, soil taxa detection and land evaluation of the area of interest, by the aid of integrating of the topographic features analysis (DEM) and image processing supplemented by field observation.

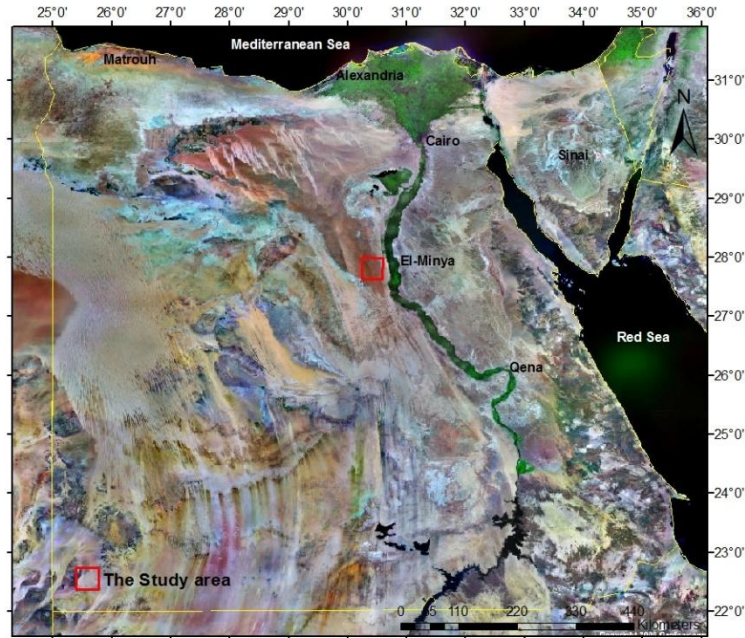


Fig (1) Location map of the study area

Materials and methods:-

Data:-

- Topographic map with 1:100,000 scale produced by Military Survey of Egypt (1969).
- Satellite data (ETM⁺ with path and row 177 and 41 respectively acquired in 2015).

Data Analysis:-

- The topographic data conversion to digital form by scanning,
- The used spatial data were geometrically corrected to Egypt Transverse Mercator (ETM), Red belt,
- The features extraction and analysis was achieved by the aid of Arc GIS 10.1 package,
- Digital Elevation Model (DEM) of the study area was built up by contour lines and spot heights extraction from the topographic map (1:100,000) and the analysis in Arc GIS 10.1,
- The main physiographic units of the region were identified aided by DEM visual interpretation and guided by Landsat ETM⁺ image. The "physiographic analysis" detailed by **Zinck and Valenzuala (1990)** were used to nominate the mapping units,

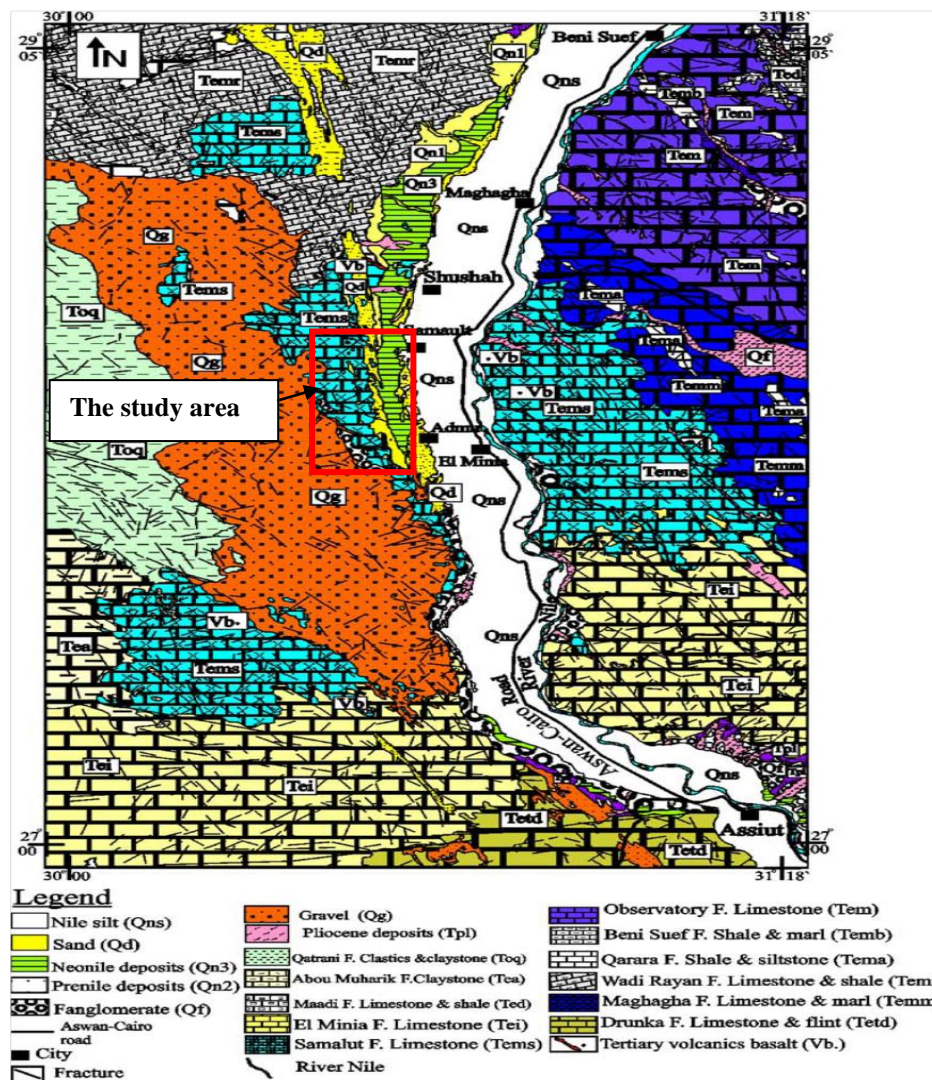


Fig (2) Geological map of El-Minya area (Conoco Coral Egypt, 1987)

- Thirty five soil profiles representing some soils of the different geomorphologic units were allocated, exposed, morphologically described (FAO, 1990) and classified (USDA, 2014). 101 soil samples were collected from the different profile layers for laboratory analyses,
- The soil samples were analyzed for particle size distribution, pH (in the soil paste) ECe (in the soil paste extract), Exchangeable Sodium Percent (ESP), CaCO_3 % and $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ % (USDA, 2004).
- Soil color was defined by Munsell Color Charts (USDA, 1975).
- Land suitability classification was carried according to Sys and Verheye (1978). The main land characteristics which are considered as limiting factors for irrigated agriculture and land use are:

t: Topographic limitation,
w: Wetness limitation (mainly based on drainage conditions),
s: limitations with regard to physical soil conditions:
s1: Textural including stoniness,
s2: Soil profile depth,
s3: Calcium carbonate status, and
s4: Gypsum status.
n: Salinity and alkalinity limitations.

Land capability index was calculated for each soil profile and consequently the land units were quantified to a certain suitability class.

The capability indices for irrigated land (Ci) could be calculated according to the following equation:

$$Ci = t \times (w/100) \times (s1/100) \times (s2/100) \times (s3/100) \times (s4/100) \times (n/100).$$

With respect to the current system, the soils are classified according to the following table guidance:

Class	Soil limitations	Capability index (Ci)
S1	Land units without or with only 3/4 slight limitations	+75
S2	Land units without or with only 2/3 moderate limitations and no more than 2/3 moderate limitations	50-75
S3	Land units without or with only 3/4 slight limitations and/or one severe limitations	25-50
N	Land units with one or more severe or very severe limitations that exclude the use of the land.	-25

Results and discussions:-

Geomorphologic units and their soil properties:

Geological map (Fig.2), Landsat ETM⁺ image (Fig.3), DEM map (Fig.4) and data verification by in situ observation were used for delineating the main geomorphologic units. It is found that the main geomorphologic units (Fig.5) in the study area are high terraces, medium high terraces, low high terraces and rock land as the following table:

Geomorphhic Unit	Area (Feddan)	%
High terraces	66327.7	19.6
Medium high terraces	156481.2	46.3
Low high terraces	103811.4	30.8
Rock land	11009.7	3.3
Total	337630	100.00

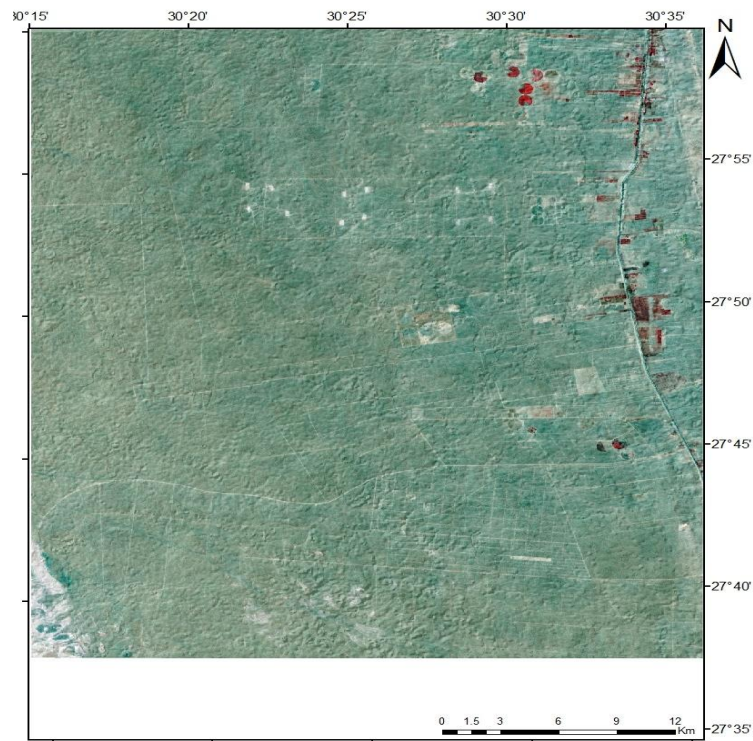


Fig (3) Subset of satellite image (ETM, path 177- row 41) covering the study area

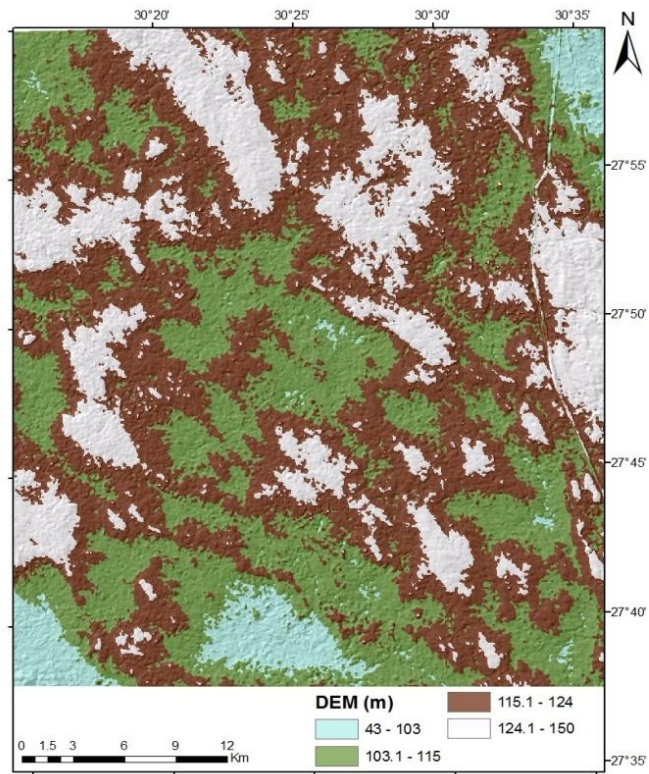


Fig (4) Digital Elevation Model (DEM) of the study area

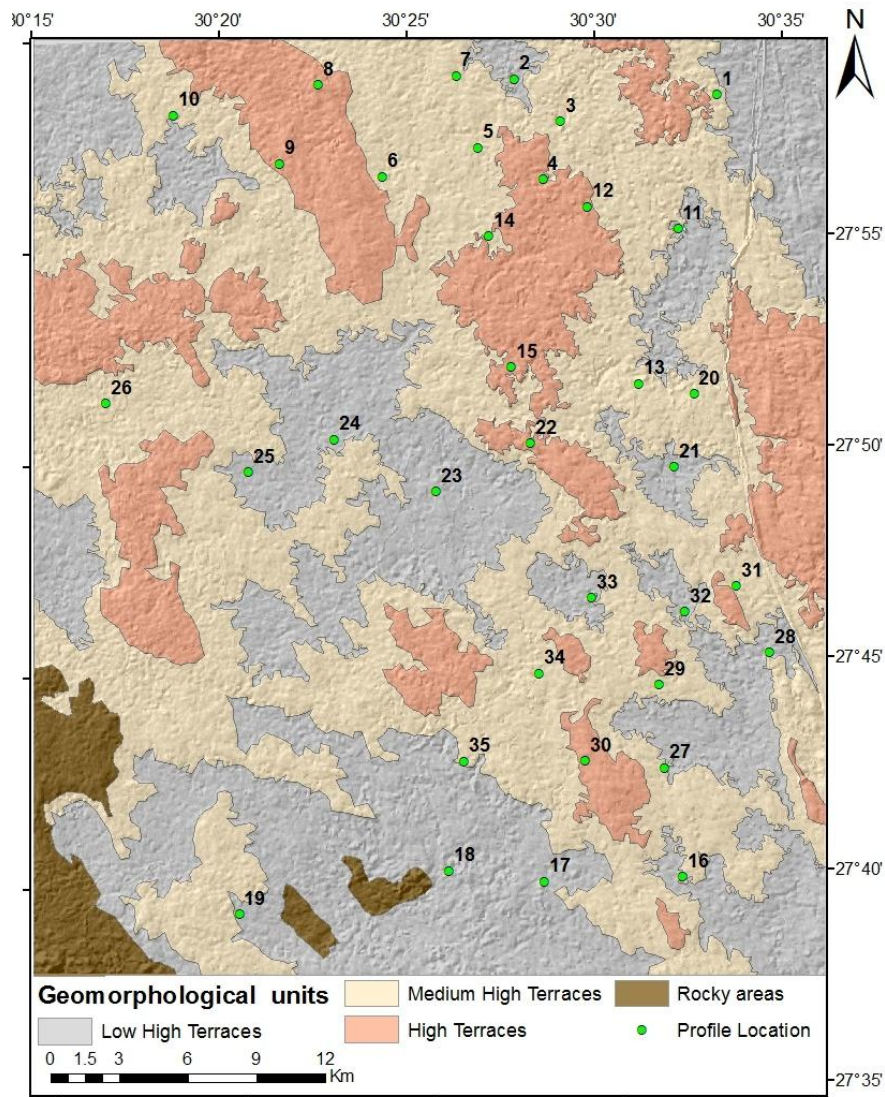


Fig. (5): Geomorphologic units and soil profile locations of the study area

Table (1): Morphological description briefing of the studied soil profiles.

Geomorphologic unit	Profile No.	Depth (cm)	Soil Color (dry)	Structure types	Gravel (by volume) %	Consistence				Secondary formation		Effervescence	Boundary
						Dry	Moist	Wet		K	Y		
								ST	PL				
High Terraces	4	0-20	10YR5/4	MA	-	HA	Fi	NST	NPL	C	C	ST	CW
		20-40	10YR5/4	MA	-	HA	Fi	NST	NPL	C	M	ST	CW
		40-120	10YR5/4	MA	10	HA	Fi	NST	NPL	C	C	ST	-
	8	0-15	10YR5/3	MA	-	HA	Fi	NST	NPL	C	F	ST	CW
		15-55	10YR5/3	MA	10	HA	Fi	NST	NPL	C	C	ST	CW
		55-100	10YR5/3	MA	15	HA	Fi	NST	NPL	M	M	ST	-
	9	0-20	10YR7/8	MA	10	HA	Fi	NST	NPL	C	M	ST	CW
		20-60	10YR6/6	MA	15	HA	Fi	NST	NPL	M	C	ST	-
	12	0-25	10YR6/6	SG	5	LO	LO	SST	SPL	C	F	ST	CW
		25-50	10YR6/8	MA	15	SHA	FR	SST	SPL	C	C	ST	CS
		50-110	10YR5/4	MA	25	SHA	FR	SST	SPL	M	F	ST	-
	15	0-20	10YR7/6	SG	-	LO	LO	SST	SPL	C	F	ST	CS
		20-60	10YR6/6	MA	3	SHA	FR	ST	PL	C	F	ST	CS
		60-120	10YR5/4	MA	5	SHA	FR	SST	SPL	M	F	ST	-
22	0-35	10YR7/6	SG	15	LO	LO	SST	SPL	C	F	ST	CS	
	35-65	10YR6/6	MA	25	SHA	FR	SST	SPL	M	F	ST	CW	
	65-130	10YR4/6	MA	15	SHA	FR	SST	SPL	M	F	ST	-	
30	0-30	10YR5/6	MA	5	SHA	FR	SST	SPL	M	F	ST	CS	
	30-60	10YR5/8	MA	10	SHA	FR	SST	SPL	M	C	ST	CW	
	60-120	10YR6/8	MA	15	SHA	FR	SST	SPL	C	F	ST	-	
Medium high Terraces	1	0-20	10YR6/8	MA	-	HA	Fi	NST	NPL	M	M	ST	CW
		20-60	10YR6/8	MA	-	HA	Fi	NST	NPL	M	C	ST	CW
		60-120	10YR6/8	MA	15	HA	Fi	NST	NPL	C	C	ST	-
	3	0-20	10YR5/5	MA	-	HA	Fi	NST	NPL	C	M	ST	CW
		20-60	10YR5/5	MA	-	HA	Fi	NST	NPL	C	C	ST	CW
		60-120	10YR5/6	MA	-	HA	Fi	SST	SPL	M	M	ST	-
	5	0-20	10YR5/4	MA	-	HA	Fi	NST	NPL	C	C	ST	CW
		20-40	10YR5/4	MA	-	HA	Fi	NST	NPL	M	C	ST	-
	6	0-25	10YR5/4	MA	-	HA	Fi	NST	NPL	M	F	ST	CW
		25-70	10YR5/4	MA	15	HA	Fi	NST	NPL	M	C	ST	CW
		70-120	10YR5/4	MA	-	HA	Fi	NST	NPL	C	C	ST	-
	7	0-20	10YR7/3	MA	-	HA	Fi	NST	NPL	M	F	ST	CW
		20-60	10YR7/3	MA	-	HA	Fi	NST	NPL	C	C	ST	CW
		60-120	10YR7/3	MA	-	HA	Fi	NST	NPL	M	M	ST	-
10	0-20	10YR7/6	MA	-	HA	Fi	NST	NPL	C	F	Mo	DW	
	20-80	10YR7/6	MA	5	HA	Fi	NST	NPL	C	F	Mo	DW	
	80-150	10YR7/6	MA	-	HA	Fi	NST	NPL	C	F	Mo	-	
13	0-20	10YR7/7	SG	-	LO	LO	SST	SPL	M	F	ST	CW	
	20-70	10YR5/4	MA	5	SHA	FR	SST	SPL	M	C	ST	CS	
	70-100	10YR6/6	MA	5	SHA	FR	SST	SPL	M	C	ST	-	
14	0-25	10YR7/7	SG	2	LO	LO	NST	NPL	M	F	ST	CS	
	25-65	10YR8/2	MA	5	SHA	FR	SST	SPL	M	C	ST	CW	
	65-130	10YR7/2	MA	10	SHA	FR	SST	SPL	C	F	ST	-	
16	0-25	10YR7/6	SG	2	LO	LO	NST	NPL	C	F	ST	CS	
	25-70	10YR6/6	MA	1	LO	LO	SST	SPL	C	F	ST	CS	
	70-120	10YR6/6	MA	3	SHA	FR	SST	SPL	C	F	ST	-	
20	0-30	10YR6/6	MA	5	LO	LO	SST	SPL	M	F	ST	CS	
	30-70	10YR5/6	MA	10	SHA	FR	SST	SPL	C	M	ST	CW	
	70-120	10YR6/8	MA	5	SHA	FR	ST	PL	C	F	ST	-	

Table (1) Cont.

Geomorphologic unit	Profile No.	Depth (cm)	Soil Color (dry)	Structure types	Gravel (by volume) %	Consistence				Secondary formation		Effervescence	Boundary
						Dry	Wet	Moist		K	Y		
								ST	PL				
Medium high Terraces	16	0-25	10YR7/6	SG	2	LO	LO	NST	NPL	C	F	ST	CS
		25-70	10YR6/6	MA	1	LO	LO	SST	SPL	C	F	ST	CS
		70-120	10YR6/6	MA	3	SHA	FR	SST	SPL	C	F	ST	-
	20	0-30	10YR6/6	MA	5	LO	LO	SST	SPL	M	F	ST	CS
		30-70	10YR5/6	MA	10	SHA	FR	SST	SPL	C	M	ST	CW
		70-120	10YR6/8	MA	5	SHA	FR	ST	PL	C	F	ST	-
	26	0-30	10YR6/6	MA	15	LO	LO	SST	SPL	C	F	ST	CS
		30-65	10YR5/6	MA	25	SHA	FR	SST	SPL	M	F	ST	CW
		65-120	10YR6/8	MA	15	SHA	FR	SST	SPL	C	F	ST	-
	29	0-30	10YR7/6	SG	5	LO	LO	NST	NPL	C	F	ST	CS
		30-60	10YR6/6	MA	5	SHA	FR	SST	SPL	C	F	Mo	CW
		60-120	10YR6/8	MA	5	SHA	FR	NST	NPL	C	F	Mo	-
	31	0-30	10YR7/6	SG	5	LO	LO	SST	SPL	M	F	ST	CS
		30-60	10YR6/6	MA	5	SHA	FR	NST	NPL	C	C	ST	CW
		60-120	10YR5/6	MA	5	SHA	FR	SST	SPL	C	F	ST	-
	34	0-30	10YR7/6	SG	5	LO	LO	NST	NPL	C	F	Mo	CS
		30-60	10YR7/8	SG	5	LO	LO	NST	NPL	C	F	Mo	CW
		60-120	10YR6/8	SG	5	LO	LO	NST	NPL	C	F	Mo	-
35	0-30	10YR5/6	MA	5	SHA	FR	SST	SPL	M	F	ST	CW	
	30-60	10YR6/6	MA	5	SHA	FR	SST	SPL	C	F	ST	CW	
	60-120	10YR5/4	MA	5	SHA	FR	SST	SPL	C	F	ST	-	
Low high Terraces	2	0-25	10YR6/6	MA	-	VHA	FR	NST	NPL	C	C	ST	CW
		25-100	10YR6/6	MA	20	VHA	FR	NST	NPL	F	C	ST	-
	11	0-25	10YR7/6	SG	5	LO	LO	NST	NPL	M	F	ST	CS
		25-60	10YR6/6	MA	7	LO	LO	SST	SPL	C	F	ST	CS
		60-120	10YR6/8	MA	15	SHA	FR	SST	SPL	C	F	ST	-
	17	0-30	10YR7/6	SG	5	LO	LO	NST	NPL	M	F	ST	CS
		30-60	10YR6/6	MA	10	SHA	FR	NST	NPL	M	F	ST	CS
		70-150	10YR5/4	MA	35	SHA	FR	SST	SPL	M	F	ST	-
	18	0-25	10YR7/6	SG	5	LO	FR	NST	NPL	C	F	ST	CS
		25-70	10YR5/4	SG	10	LO	FR	NST	NPL	C	C	ST	CS
		70-130	10YR6/8	SG	25	LO	FR	SST	SPL	M	F	ST	-
	19	0-20	10YR7/6	MA	5	LO	LO	NST	NPL	M	C	ST	CS
20-40		10YR7/2	MA	3	SHA	FR	NST	NPL	M	C	ST	CW	
40-70		10YR6/8	SG	3	SHA	FR	SST	SPL	C	C	ST	CS	
70-150		10YR5/4	MA	5	LO	LO	SST	SPL	C	F	ST	-	
21	0-30	10YR6/6	MA	20	LO	LO	SST	SPL	C	F	ST	CW	
	30-60	10YR6/8	MA	25	SHA	FR	ST	PL	C	F	ST	CS	
	60-120	10YR5/6	MA	15	SHA	FR	SST	SPL	C	F	ST	-	
23	0-30	10YR7/6	MA	15	LO	LO	SST	SPL	C	F	ST	CS	
	30-70	10YR5/6	MA	25	SHA	FR	SST	SPL	C	F	ST	CW	
	70-120	10YR6/8	MA	20	SHA	FR	SST	SPL	C	F	ST	-	

Table (1) Cont.

Geomorphologic unit	Profile No.	Depth (cm)	Soil Color (dry)	Structure types	Gravel (by volume) %	Consistence				Secondary formation		Effervescence	Boundary
						Dry	Wet	Moist		K	Y		
								ST	PL				
Low high Terraces	24	0-25	10YR7/6	MA	15	LO	LO	SST	SPL	C	F	ST	CS
		25-60	10YR5/6	MA	15	SHA	FR	SST	SPL	M	C	ST	CW
		60-120	10YR4/4	MA	10	SHA	FR	SST	SPL	C	F	ST	-
	25	0-20	10YR7/6	MA	15	SHA	FR	ST	PL	M	C	ST	CS
		20-70	10YR5/6	MA	25	SHA	FR	SST	SPL	C	C	ST	CW
		70-120	10YR4/4	MA	25	HA	Fi	SST	SPL	C	C	ST	-
	27	0-30	10YR7/6	MA	15	SHA	FR	ST	PL	C	F	ST	CS
		30-60	10YR6/8	MA	25	SHA	FR	ST	PL	C	C	ST	CW
		60-100	10YR4/4	MA	25	HA	Fi	ST	PL	C	C	ST	-
	28	0-30	10YR6/6	MA	5	SHA	FR	ST	PL	M	F	ST	CS
		30-65	10YR5/6	MA	5	SHA	FR	SST	SPL	C	F	ST	CW
		65-120	10YR6/8	MA	5	SHA	FR	SST	SPL	C	F	ST	-
	32	0-25	10YR6/6	MA	10	SHA	FR	SST	SPL	C	F	ST	CS
		25-65	10YR6/8	MA	5	SHA	FR	SST	SPL	C	F	ST	CW
		65-120	10YR5/4	MA	15	SHA	FR	SST	SPL	C	F	ST	-
	33	0-30	10YR7/6	SG	5	LO	LO	NST	NPL	C	F	ST	CS
		30-60	10YR6/6	MA	5	SHA	FR	SST	SPL	C	F	ST	CW
		60-120	10YR6/8	SG	5	LO	LO	NST	NPL	C	F	ST	-

Abbreviations used in Table (1) and their correspondence (FAO, 1990 and Soil Survey Manual, 1984):

Structure Types	Plasticity(PL)	Effervescence
MA : Massive	NPL : Non Plastic	ST : Strongly calcareous
SG : Single grains	SPL : Slightly Plastic	Mo : Moderate calcareous
Consistence	PL : Plastic	Boundary
LO : Loose	Secondary Formation	C : Clear
HA : Hard	K : Accumulation of Carbonates	S : Smooth
SHA : Slightly hard	Y : Accumulation of Gypsum	W : Wavy
FR : Friable	F : Few (2-5%)	
Fi : Firm	C : Common (5-15%)	
Sticky (ST)	M : Many (15-40%)	
NST : Non Sticky		
SST : Slightly Sticky		
ST : Sticky		

Field morphological descriptions of the studied soil profiles are summarized in Table (1). Certain laboratory analyses that are used to pursue land evaluation and soil classification are present in Table (2). Brief descriptions of the soils of the different physiographic units are discussed hereafter:

1- High Terraces: From 124.1 to 150 m high:- This unit is undulating to gently undulating relief and their soils are mostly deep. Table (2) shows that the soils exert particle size classes of gravelly sand to gravelly sandy loam with clay content ranged from 3.8 to 24.6 %, Their salinity is mostly medium to extremely saline (ECe values ranged from 3.24 to 55.4 dS/m). The high salinity is due to aridity prevalence and lacks of the precipitation in most of the year, exceptionally the sudden flash floods which may take place in some years. The soils are neutral in reaction as

the pH values ranged between 6.9 and 7.7. Calcium carbonate contents varied from 9.2 to 20.0% and gypsum content ranged from 3.4 to 15.5%. This unit is represented by profiles No. 4,8,9,12,15,22 and 30.

2- Medium high Terraces: From 115.1 to 124 m. high:-

This unit is gently undulating and their soils are deep to very deep. Table (2) shows that the soils possess particle size classes of gravelly sand to sandy loam with clay content varied between 3.8 and 22.1 %. Salinity are non to extremely saline (ECe values ranged from 0.51 to 156.8 dS/m). The pH values ranged between 6.8 and 7.89. Calcium Carbonate contents ranged from 8.8 to 24.4%, gypsum content ranged from 3.0 to 15.7%. This unit is represented by profiles No. 1, 3,5,6,7,10,13,14,16,20,26,29,31,34 and 35.

3- Low high Terraces: From 43 to 115 m high:-

This unit is almost flat and their soils are mostly deep very deep. Table (2) show that the soils exhibit particle size classes of gravelly sandy to sandy clay loam and clay content ranged from 4.1 and 26.7 %. The salinity are medium to extremely saline (ECe values ranged from 4.1 to 104.7 dS/m). The pH values ranged between 6.8 and 7.8. Calcium carbonate contents varied from 2.7 to 18.0 % and gypsum content ranged from 1.8 to 10.6 %. This unit is represented by profiles No. 2,11,17,18,19,21,23,24,25,27,28,32 and 33.

Table (2): Some Physicochemical properties of the studied soil profiles.

Geomorphologic Unit	Profile No.	Depth (cm)	Sand %		Silt %	Clay %	pH	ECe (dS/m)	ESP	CaCO ₃ %	Gypsum %	Modified Texture class
			Coarse	Fine								
High terraces	4	0-20	68.7	20.8	6.6	3.9	7.13	20.1	6.4	10.4	10.4	S
		20-40	68.4	19.1	7.3	4.2	7.6	3.24	12.9	9.2	15.5	S
		40-120	70.3	18.1	7.8	3.8	7.5	4.93	11.3	12.4	10.4	S
	8	0-15	71.1	17.1	6.5	5.3	7.19	10.96	11.5	16.4	3.8	S
		15-55	74.3	13.6	7.2	4.9	7.4	7.87	14.6	14.0	10.2	S
		55-100	68.2	18.8	7.9	5.1	7.3	11.74	18.8	12.4	15.4	GS
	9	0-20	75.2	10.5	8.1	6.2	7.4	9.44	9.7	10.8	15.3	S
		20-60	70.5	16.9	7.5	5.3	7.4	8.01	16.9	18.0	10.4	GS
	12	0-25	57.9	13.4	14.8	13.9	7.3	9.21	34.8	12.0	3.4	SL
		25-50	59.2	14.6	13.3	12.9	7.2	21.5	33.9	13.6	10.2	GSL
		50-110	53.3	19.5	14.9	12.3	7.1	26.9	35.4	16.0	5.7	GSL
	15	0-20	66.3	8.8	13.4	11.5	7.1	17.58	15.4	13.3	4.2	LS
		20-60	42.4	10.7	32.3	24.6	6.9	55.4	43.6	10.0	7.3	SCL
		60-120	58.1	16.3	11.1	14.6	7.1	38.7	19.8	17.2	5.4	LS
	22	0-35	62.3	14.2	12.4	11.1	7.6	4.6	16.6	12.0	3.6	GSL
		35-65	56.9	19.3	11.7	13.1	7.5	16.9	17.3	17.5	3.7	GSL
		65-130	57.9	18.7	13.6	10.8	7.6	20.5	16.7	20.0	3.5	GSL
	30	0-30	40.6	22.8	21.7	14.9	7.5	17.2	17.9	17.0	5.6	SL
30-60		43.3	20.9	22.1	13.8	7.5	54.1	18.4	17.0	15.3	SL	
60-120		41.7	20.9	23.2	14.2	7.7	46.0	17.8	12.0	5.4	SL	
Medium high Terraces	1	0-20	70.2	20.1	5.2	4.5	7.42	23.3	10.2	17.6	15.5	S
		20-60	68.7	19.5	7.9	3.9	6.93	65.3	11.4	17.6	10.6	S
		60-120	65.2	23.1	6.8	4.9	7.3	45.2	12.7	12.0	5.4	GS
	3	0-20	71.1	17.0	6.6	5.3	7.32	21.5	11.7	14.0	15.7	S
		20-60	73.2	14.2	7.8	4.8	7.41	10.34	13.9	10.0	10.8	S
		60-120	60.1	10.1	15.0	14.5	7.4	7.4	33.8	18.0	15.6	SL
	5	0-20	72.1	17.7	6.5	3.7	7.5	8.1	13.5	13.6	10.3	S
		20-40	71.9	16.4	7.2	4.5	7.6	4.2	16.9	24.4	5.6	S
	6	0-25	70.2	17.4	7.5	4.9	7.6	4.21	10.6	15.6	4.8	S
		25-70	69.5	19.2	7.1	4.2	7.4	8.71	12.3	21.2	10.4	GS
		70-120	69.7	19.5	6.9	3.9	7.1	21.9	15.3	13.2	10.5	S
	7	0-20	71.2	19.1	5.9	3.8	7.1	26.8	9.6	18.4	5.4	S
		20-60	72.3	17.2	6.4	4.1	7.12	16.7	12.3	13.3	10.6	S
		60-120	70.9	16.4	7.5	5.2	6.8	156.8	19.7	19.2	15.7	S
	10	0-20	71.7	15.2	8.2	4.9	7.6	4.16	11.7	8.8	4.3	S
		20-80	67.2	20.4	8.5	3.9	7.4	10.46	13.2	9.2	3.7	S
		80-150	66.7	20.2	7.9	5.2	7.2	27.7	21.7	10.8	3.8	S
	13	0-20	58.1	13.4	14.7	13.8	7.7	5.73	32.3	15.2	4.3	SL
20-70		52.4	35.4	12.4	14.2	7.4	9.85	36.4	16.6	10.2	SL	
70-100		60.5	12.2	14.6	12.7	7.2	31.2	37.2	17.6	5.6	SL	
14	0-25	65.8	22.6	6.8	4.8	7.7	3.2	9.8	18.4	4.5	S	
	25-65	56.2	16.1	13.8	13.9	7.3	17.89	32.9	24.0	10.2	SL	
	65-130	57.6	15.6	12.5	14.3	7.1	20.8	33.9	12.2	4.3	SL	
16	0-25	76.7	13.3	5.4	4.6	7.3	19.85	10.6	12.0	4.6	S	
	25-70	66.3	10.2	9.9	13.6	7.3	12.56	15.8	10.8	3.4	LS	
	70-120	66.7	10.2	8.7	14.4	7.2	15.89	14.9	9.6	3.3	LS	
20	0-30	59.3	15.7	13.4	11.6	7.7	5.0	15.9	18.0	5.6	SL	
	30-70	61.5	14.4	12.9	11.2	7.7	10.1	16.2	19.0	15.2	SL	
	70-120	51.4	8.5	17.6	22.1	7.7	41.2	43.5	10.5	3.7	SCL	
26	0-30	43.9	18.8	21.4	15.9	7.6	39.6	38.2	14.0	3.3	GSL	
	30-65	45.3	17.2	22.7	14.8	7.6	29.5	38.7	16.0	3.5	GSL	
	65-120	44.3	18.9	23.1	13.7	7.7	24.4	40.6	12.0	3.1	GSL	

	Profile No.	Depth (cm)	Sand %		Silt %	Clay %	pH	ECe (dS/m)	ESP	CaCO ₃ %	Gypsum %	Modified Texture class	
			Coarse	Fine									
	29	0-30	70.3	21.1	4.7	3.9	7.8	3.39	11.3	9.0	3.5	S	
		30-60	57.2	20.5	14.4	7.9	7.8	3.29	19.2	9.0	3.6	LS	
		60-120	73.9	12.4	6.5	7.2	7.7	3.21	11.9	9.0	3.4	S	
	31	0-35	56.3	21.1	9.5	14.1	7.8	3.93	22.7	16.0	3.0	LS	
		35-70	65.8	21.7	7.7	4.8	7.7	9.48	16.6	14.0	8.2	S	
		70-120	56.4	20.4	9.3	13.9	7.7	16.85	25.3	14.0	3.6	LS	
	34	0-30	71.8	14.9	8.2	5.1	7.83	1.2	10.9	12.0	3.5	S	
		30-60	69.4	16.9	7.9	5.9	7.85	0.95	15.6	9.0	3.1	S	
		60-120	65.7	20.5	9.1	4.7	7.89	0.51	19.6	9.0	3.6	S	
	35	0-30	49.3	26.7	11.2	12.8	7.72	5.77	19.8	18.0	3.4	LS	
		30-60	48.4	34.6	10.7	14.3	7.68	7.52	22.7	19.0	3.6	LS	
		60-120	42.3	32.3	12.3	13.1	7.57	8.8	36.9	14.0	3.4	LS	
	Low high terraces	2	0-25	70.5	17.6	6.3	5.6	7.4	9.62	10.6	13.6	10.3	S
			25-100	69.8	18.2	7.1	4.9	7.33	17.54	12.3	2.7	10.6	GS
		11	0-25	66.3	20.6	7.9	5.2	7.6	6.8	6.7	18.0	3.6	S
25-60			66.2	8.3	11.2	14.3	6.9	53.1	17.8	12.0	1.8	LS	
60-120			43.6	20.3	23.3	15.4	6.83	64.1	37.9	12.8	2.6	GSL	
17		0-30	70.3	19.8	4.6	5.3	7.3	10.07	11.6	18.0	3.4	S	
		30-60	79.6	9.9	5.4	5.1	6.9	53.1	14.3	17.6	3.5	S	
		70-150	62.2	9.1	14.6	14.1	7.2	25.8	19.6	15.6	3.5	GLS	
18		0-25	69.1	17.3	7.3	6.3	6.8	104.7	12.7	11.2	3.9	S	
		25-70	78.7	9.7	6.9	4.7	7.3	27.3	16.3	12.0	7.4	S	
		70-130	63.8	13.6	8.7	13.9	7.6	16.1	25.5	16.0	3.5	GLS	
19		0-20	79.2	8.7	6.4	5.6	7.8	4.1	11.8	15.5	7.3	S	
		20-40	71.4	19.3	5.2	4.1	7.6	15.5	15.6	15.0	8.3	S	
		40-70	56.8	17.7	10.2	14.3	7.8	24.1	19.8	10.5	5.4	LS	
		70-150	58.2	10.2	9.8	13.9	7.2	60.2	22.4	14.0	3.8	LS	
21	0-30	52.4	10.1	21.3	12.6	7.6	36.7	16.7	14.5	3.5	GSL		
	30-60	53.6	7.7	18.3	20.4	7.5	24.1	17.2	18.5	3.4	GSCl		
	60-120	60.9	16.1	12.3	10.7	7.6	30.5	19.9	13.0	3.3	GSL		
23	0-30	42.6	19.5	22.7	15.2	7.7	9.8	15.8	13.5	2.5	SL		
	30-70	41.2	18.1	24.6	16.1	7.7	15.6	17.3	13.5	3.6	SL		
	70-120	43.4	19.9	21.8	14.9	7.8	4.3	16.5	12.0	2.4	SL		
24	0-25	42.3	20.2	23.9	13.9	7.5	6.4	17.8	13.0	5.2	GSL		
	25-60	44.2	18.8	20.9	16.1	7.7	22.7	17.6	16.0	10.4	GSL		
	60-120	39.8	19.6	23.4	17.2	7.4	4.4	18.4	14.5	5.3	SL		
25	0-20	36.4	17.1	25.8	20.7	7.7	28.9	32.5	16.0	5.6	GSCl		
	20-70	44.3	18.2	21.8	15.7	7.7	5.26	34.3	13.3	10.6	GSL		
	70-120	40.6	21.2	21.8	16.4	7.6	34.2	36.2	14.0	10.5	GSL		
27	0-30	39.4	8.9	25.3	26.7	7.7	37.7	39.4	12.0	5.3	GSCl		
	30-60	40.3	9.7	24.6	25.4	7.7	36.6	40.2	14.0	10.4	GSCl		
	60-100	42.7	8.1	25.3	23.9	7.6	13.3	42.7	14.0	10.5	GSCl		
28	0-30	38.1	19.9	22.6	19.4	7.5	24.1	44.3	17.0	4.3	SCL		
	30-65	43.7	19.5	22.3	14.5	7.6	45.4	36.4	14.0	4.0	SL		
	65-120	42.6	19.9	21.9	15.6	7.8	27.6	38.5	14.0	3.9	SL		
32	0-25	42.3	21.6	22.2	13.9	7.6	3.46	16.8	15.0	2.8	SL		
	25-65	44.2	19.1	22.6	14.1	7.7	17.48	18.2	19.0	2.4	SL		
	65-120	45.3	19.1	21.8	13.8	7.7	33.0	17.7	15.0	3.6	GSL		
33	0-30	70.4	16.0	8.4	5.2	7.71	4.99	12.8	13.0	3.1	S		
	30-60	48.4	24.3	13.1	14.2	7.8	5.31	18.3	12.0	3.3	LS		
	60-120	65.5	21.8	7.8	4.9	7.8	10.15	11.9	10.0	3.9	S		

G: gravelly (15-35%)

SL: Sandy Loam

LS: Loamy Sand

SCL: Sandy Clay Loam

S: Sand

Soil Classification:-

Soil taxonomy is the standard reference used in organizing and communicating knowledge about soils. The soil classification system is used to provide means for understanding the relationships among soils within a given area and among soils in different landforms. It can be used as reference term to identify soil mapping units (**USDA, 1983**).

The classification of soil under investigation is carried out according to (**USDA, 1975**) and its keys (**USDA 2014**). This system is based on the following:

1. Soil moisture and temperature regime,
2. Morphological characteristics,
3. Chemical and mineralogical composition, and
4. Presence or absence of diagnostic horizons.

According to this system, two soil orders are identified in the study area i.e. *Aridisols* and *Entisols* (Table 3). These orders are differentiated into suborders, great groups and subgroups based on criteria outlined in the **U.S. Soil Taxonomy System (2014)**. Subgroups are further differentiated into families (Table 3).

1-Aridisols:

These soils were developed under the aridic moisture regime and hyperthermic temperature regime. They include one or more of the diagnostic horizons as calcic, gypsic and salic. The soils of this order are widely spread in the study area. Two *Aridisols* suborders are identified in the study area, namely; *Calcids* and *Gypsid*s. *Aridisols* can further be differentiated down to families as follows (Table 3):

- *Typic Calcigypsid*s, sandy, mixed, hyperthermic (Profiles N_o.1, 2, 3, 4, 6, 7, 8, 9, 15 and 19).
- *Typic Calcigypsid*s, coarse loamy, mixed, hyperthermic (Profiles N_o. 12, 13, 14, 18, 24, 25, 27 and 31).
- *Lithic Calcigypsid*s, sandy, mixed, hyperthermic (Profiles N_o.5).
- *Typic Haplocalcid*s, coarse loamy over clayey, mixed, hyperthermic (Profile N_o.20, 22, 23, 26, 28, 30 and 32).
- *Typic Haplocalcid*s, fine loamy, mixed, hyperthermic (Profiles N_o.21).
- *Typic Haplocalcid*s, sandy, mixed, hyperthermic (Profiles N_o. 17 and 35).

2-Entisols:

Entisols are the recent soils that are not exhibiting any sign of parent material maturity under the prevailing arid climate. However, according to **Smith (1986)** *Entisols* lack the subsurface diagnostic horizons. Soils of this order are low spread in the middle and low terraces units. One *Entisols* suborder is identified in the study area, namely; *Orthents*.

These soils were differentiated to family level as follows:

- *Typic Torriorthents*, sandy, mixed, hyperthermic (Profiles N_o. 10, 11, 16, 29, 33 and 34).

Table (3): Soil classification of the study area.

Geomorphic Unit	Profile No.	Order	Sub order	Great group	Sub great group	Family	
High Terraces	4	<i>Aridisols</i>	<i>Gypsis</i>	Calcigypsis	Typic Calcigypsis	Sandy, Mixed, hyperthermic.	
	8					Coarse loamy, Mixed, hyperthermic.	
	9						
	15						
	12						
	22						
30	<i>Calcids</i>		Haplocalcids	Typic Haplocalcids	Coarse loamy, Mixed, hyperthermic.		
Medium High Terraces	1		<i>Aridisols</i>	<i>Gypsis</i>	Calcigypsis	Typic Calcigypsis	Sandy, Mixed, hyperthermic.
	3						Coarse loamy, Mixed, hyperthermic.
	6						
	7						
	13						
	14						
	31	Lithic Calcigypsis		Sandy, Mixed, hyperthermic.			
	5			Sandy, Mixed, hyperthermic.			
	35	<i>Calcids</i>		Haplocalcids	Typic Haplocalcids	Coarse loamy, Mixed, hyperthermic.	
	20					Sandy, Mixed, hyperthermic.	
	26						
	10						
	16	<i>Entisols</i>	<i>Orthent</i>	Torriorthents	Typic Torriorthents		Sandy, Mixed, hyperthermic.
	29						
34							
2	<i>Aridisols</i>					<i>Gypsis</i>	Calcigypsis
19		Coarse loamy, Mixed, hyperthermic.					
18							
24							
25							
27			<i>Entisols</i>	<i>Orthent</i>	Torriprthents		
17						Fine loamy, Mixed, hyperthermic.	
21		Coarse loamy, Mixed, hyperthermic.					
23							
28							
32							
11							
33							

Land suitability for irrigated agriculture:-**A) Current land suitability:-**

Applying the land classification system of **Sys and Verheye (1978)** to the soils of the study area, (Table 4) reveals that the current suitability of these soils can be placed at the following classes:

1- Soils of class S2:-

The soils of this class have capability index ranging from 50 to 75 and represented by profiles No. 21 (low terraces unit) and 22 (High terraces unit). These soils have moderate limitations that differ in their kind and degree.

2- Soils of Class S3:-

Soils belonging to class S3 have capability index ranging from 25 to 50. These soils are prevailing in the study area. The soils of this class are affected by moderate and severe limitations that differ in their kind and degree.

3- Soils of Class N:-

Soils belonging to class N have capability index less than 25. These soils are partly distributed in the study area. The soils of this class are affected by severe limitations that differ in their kind and degree.

The most limiting factors in the studied soils are texture, salinity followed by profile depth and gypsum content, however topography represent minor limitations.

B) Potential land suitability:-

Further land improvement is required to correct or reduce the severity of limitations according to **Sys et al (1991)** existing in the study area such as:

- a) Leaching of soils salinity and reclamation of soil sodicity,
- b) Continuous application of organic manure to improve soil properties and fertility status, and
- c) Application of drip and sprinkler irrigation system.

By applying these practices, potential suitability of the studied soils could be ameliorated to highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and little areas of not suitable (N1) (Table 4).

Table (4): * Degree of soil limitations and suitability classes of the studied soil profiles.

Geomorphologic Unit	Profile No.	t		w		Soil physical characteristics(s)					n		Ci		Suitability classes	
		c	p	c	p	s1		s2	s3	s4	c	p	c	p	c	p
						c	p									
High Terraces	4	85	100	100	100	30	50	90	100	80	90	100	16.5	36.0	N1	S3
	8	90	100	100	100	30	50	90	100	80	90	100	17.5	36.0	N1	S3
	9	90	100	100	100	30	50	75	100	80	90	100	14.6	30.0	N1	S3
	12	85	100	100	100	45	60	90	100	100	75	100	25.8	54.0	S3	S2
	15	90	100	100	100	80	85	75	100	100	58	100	31.3	63.8	S3	S2
	22	90	100	100	100	95	95	90	100	100	80	100	61.5	85.5	S2	S1
	30	90	100	100	100	75	80	90	100	100	58	100	35.2	72.0	S3	S2
Medium high Terraces	1	95	100	100	100	30	50	90	100	80	80	100	16.4	36.0	N1	S3
	3	95	100	100	100	45	60	90	100	80	80	100	24.6	43.2	N1	S3
	5	95	100	100	100	30	50	55	100	100	90	100	14.1	27.5	N1	S3
	6	95	100	100	100	30	50	90	100	100	90	100	23.1	45.0	N1	S3
	7	95	100	100	100	30	50	90	100	80	85	100	17.4	36.0	N1	S3
	10	95	100	100	100	30	50	100	95	100	75	100	20.3	47.5	N1	S3
	13	85	100	100	100	30	50	90	100	100	58	100	13.3	45.0	N1	S3
	14	85	100	100	100	60	65	100	100	100	75	100	38.3	65.0	S3	S2
	16	95	100	100	100	45	60	90	100	100	85	100	32.7	54.0	S3	S2
	20	90	100	100	100	80	85	90	100	100	75	100	48.6	76.5	S3	S1
	26	95	100	100	100	75	80	90	100	100	58	100	37.2	72.0	S3	S2
	29	95	100	100	100	55	65	90	95	100	90	100	40.2	55.6	S3	S2
	31	95	100	100	100	55	65	90	100	100	80	100	37.6	59.4	S3	S2
	34	95	100	100	100	30	50	90	95	100	90	100	21.9	42.8	N1	S3
35	95	100	100	100	55	65	90	100	100	88	100	41.4	58.5	S3	S2	
Low high Terraces	2	90	100	100	100	30	50	75	100	55	90	100	10.0	20.6	N2	N1
	11	95	100	100	100	60	65	90	100	100	75	100	38.5	58.5	S3	S2
	17	90	100	100	100	55	65	100	100	100	75	100	37.1	65.0	S3	S2
	18	90	100	100	100	35	55	100	100	100	58	100	18.3	55.0	N1	S2
	19	95	100	100	100	45	60	100	100	100	58	100	24.8	60.0	N1	S2
	21	95	100	100	100	90	90	90	100	100	75	100	57.7	81.0	S2	S1
	23	90	100	100	100	75	80	90	100	100	80	100	48.6	72.0	S3	S2
	24	90	100	100	100	75	80	90	100	100	80	100	48.6	72.0	S3	S2
	25	90	100	100	100	85	85	90	100	100	58	100	49.9	76.5	S3	S1
	27	90	100	100	100	95	95	90	100	100	58	100	44.6	85.5	S3	S1
	28	95	100	100	100	85	85	90	100	100	58	100	42.2	76.5	S3	S1
	32	95	100	95	100	75	80	90	100	100	75	100	45.7	72.0	S3	S2
33	95	100	95	100	55	65	90	100	100	90	100	40.2	58.5	S3	S2	

t = Topography w= wetness s1= texture s2 = soil depth s3= CaCO₃ s4= CaSO₄.2H₂O n= salinity & alkalinity c= current p=potential Ci=Capability index

* no (95-100), slight (85-95), moderate (60-85) severe (45-60), very severe (<45).

References:-

1. CONOCO (1987): Geological map of Egypt 1:50000.NH 36 NW CAIRO, Egypt.
2. Dent, D. and A. Young, (1981): Soil Survey and Land Evaluation. George Allen and Unwin, London.)
3. Egyptian Metrological Authority (2010) Climatic Atlas of Egypt, published by Ministry of Transport Arab Republic of Egypt.
4. FAO, (1978): Report on the Agro-ecological zones project. World Soil Resources Report 48. FAO, Rome
5. FAO (1990): Guidelines for soil profile description. 3rd Edition, Rome.
6. Smith, G. (1986): The Guy. Smith interviews; Rational for concepts in soil taxonomy. USDA- SMSS.,Tech. Monograph No., 11, Washington, D.C., USA.
7. Sys, C. and Verheye (1978): An attempt to the evaluation of physical land characteristics for irrigation according to the FAO framework for land evaluation.
8. Sys, C.; E. Van Ramst; J. Debaveye and F. Beernaert (1991): "Land Evaluation". Parts I, II and III. Agric. Puplic. No. 7, GADC, Brussels, Belgium.
9. USDA (1975): Soil munssel color charts, USDA soil conserve Washington, D.C.
10. USDA (1983): National soil handbook USDA Agric. Handbook 430, US Gov. Print off., Was., D.C., USA.
11. USDA (1984): Soil Survey Manual, Soil conservation service, Washington D.C. 200/3, USA.
12. USDA (2004): Soil Survey Laboratory Methods Manual, Soil Survey Investigation Report, No. 42, Version 4.0 November, Washington, USA.
13. USDA (2014): "Keys to Soil Taxonomy". 12th (Ed), NRCS; USA.
14. Zinc, J.A. and Valenzuela (1990): "Soil Geographic Database", Vol.3, ITC, Ensched, Netherlands.