Soil Classification and Optimum Agricultural Use for Some Areas at the Western Desert Fringe, El-Minia Governorate, Egypt

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ABSTRACT

The present study has been carried out to highlight the optimal agricultural use of the different soil taxa units common in the Western desert fringe of El-Minia Governorate – Middle Egypt. This investigation is based on remote sensing data, GIS facilities, as well as outputs of the regular grid survey system. Geomorphologically, the whole area is an alluvial plain with different topography gradient varying from almost flat, gently undulating and undulating. Taxonomically, soils could be classified into (*Typic, Lithic Torripsamments* and *Typic, Lithic Torriorthents – Entisols*); (*Typic, Lithic Haplogypsids and Typic Calcigypsids – Aridsols*). Concerning the land suitability for crops, based on ALMAGARA model, "the deep and moderately deep, moderately coarse-texrured soils" vary between the suitable and moderately suitable classes (S2 and S3); whereas "the deep and moderately deep, coarse-textured soils" and "shallow soils" belong to the marginally suitable class (S4). The very shallow soils have been actually found not suitable for the tested crops. In terms of their suitability amplitude, the tested crops could be arranged as olive > peach > citrus > wheat > potato > sunflower > sugar beet > maize > melon > soybean. The study also indicated that about 32.3 % to 54% of the area regarded suitable for orchard, whereas 52% of the area is moderately suitable for the other crops and areas ranged from 5.3% to 11.8% are not suitable for the most tested crops. The outputs of this investigation may help in acquiring sustainable management and participatory agricultural development process for recently reclaimed desert areas.

Key Words: Soil Classification, Land Suitability, Micro LEIS, Remote Sensing, GIS and El-Minia Governorate.

INTRODUCTION

In Egypt, the agricultural development is considered the mainstay of the national economy upturn, in coping with the current challenges due to the striking population growth rate sequels, contemporaneous with the limited cultivable land area. Yossif (2019) denoted that, due to the irrational land use and urbanization, the cultivated land decreased by about 3.3% from 2000 to 2019. In this connection, the governmental authority decided to reclaim about 1.5 million feddans in different regions of which the study area.

Noteworthy to evidence that successful land reclamation plan should be based on full comprehensive pedogeological aspects. Land evaluation is the process of estimating the potentials of land for alternative uses. There are many models and computer packages for simulating the land evaluation applications for land use planning (FAO, 1993 and 2007). According to Dent and Young (1981), land evaluation includes different productive uses i.e. arable farming, livestock production and forestry together with other benefits.

With regard to soil suitability, ALMAGRA model constituent of Micro LEIS DSS (De la Rosa *et al.,* 2004) took into consideration the generally accepted norms mentioned by Klingebiel and Montgmery (1961); FAO (1976); Dent and Young (1981); ONERN (1982); Verheye (1986). The model works interactively, comparing the values of the characteristics of the land unit to be evaluated with the general levels established of each suitability class for particular crop.

Concerning the Sustainable Land Management (SLM), Dumanski and Smyth (1994) evidenced that it is as a system combining policies, technologies and activities aiming to integrate socio-economic basis with environmental concerns, so as to maintain or even enhance the productivity, to reduce the risk level, to protect the natural resources and be economically viable and socially accepted. Once land use potential has been determined, land evaluation can be used as a strategic tool for land use planning (FAO, 1993; Rossiter, 1996; Hedia and Abd Elkawy, 2016).

Remote sensing has been used as a tool for soil survey (Palacios-Orueta and Ustin, 1998). Geographic information systems play a major role in spatial decision-making processes (Foote and Lynch, 1996).

The present study aims mainly at determining the common soil characteristics, classifying soils and evaluating their agricultural suitability for certain crops so as to propose different crop alternatives and to recommend an appropriate sustainable management system.

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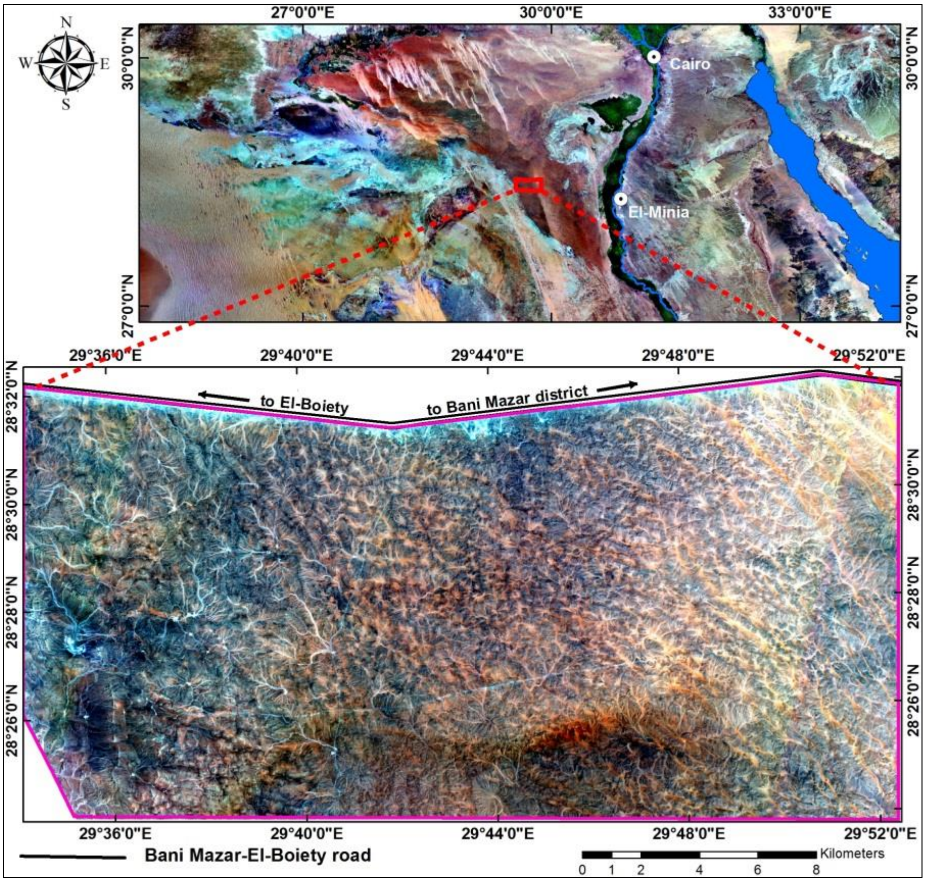
DESCRIPTION OF THE STUDY AREA

The study area is located to the west of El-Minia Governorate, south of (Bani Mazar - El-Boiety) road with about 33.5 km in length. It lies between longitudes 29º 34` 07`` and 29º 52` 35`` E. and latitudes 28º 23` 50`` and 28º 32` 08`` N., map (1), covering an area of approximately 100.000 feddans.

Climatically, data by the Egyptian Meteorological Authority (2019) show clearly that the study area falls within the arid region, marked by long hot rainless summer and mild winter with scanty rainfall. The air temperature recorded was 33.1, 23.0 and 10.6 Cº as maximum, annual average, and minimum values, respectively. Evaporation is usually fairly high than precipitation. The average daily evaporation ranges from 1.8 mm in January to 7.9 mm in June. Relative humidity distribution throughout the year ranges between 52% in April and 66% in December. The mean monthly wind velocity ranges from 7.0 to 9.1 km/hr, whereas the annual mean is 8 km / hr.

Based on the previously discussed data and in terms of the norms given in Soil Taxonomy System (USDA Soil Survey Staff, 2014a), the soil studied have thermic temperature and torric soil moisture regimes. Therefore, physical weathering is considered the ordinary factor affecting soil materials. In addition, considerable concern should be directed towards the ground water as a substantial source for irrigation in the study area.

Geologically, Said (1993) indicated that the Eocene formations in the Western Desert are veneered with Oligocene epoch clastics (gravel and cobbles and sand). The Eocene formation may crop out locally to the land surface. These facts were correlated fairly well by EGPC - Conco Coral Staff (1987) who denoted that Gabel Qatrani formation is a sequence of continental to marine alternating clastics, burrowed siltstone, and reddish clay stone.



Map 1. Location of the study area at the west of El-Minia, Egypt.

MATERIALS AND METHODS

The present investigation is based on a combination of remote sensing method and the conventional regular grid system so as to distinguish the prevailing landscape units and to define their associated soil types.

Considering the visual and digital interpretation (Lillesand and Kiefer, 2007), the Sentinel-2A satellite image - Multispectral Imager (MSI), Band 12, 8, 3 with 10m spatial resolution, (N0214_R064_T35RQM) was downloaded from the European Space Agency's (ESA) Sentinel Scientific Data Hub (ESA, 2020).

Satellite image was merged and processed with Digital Elevation Model (SRTM-C) of 12.5 m spatial resolution, obtained from USGS (2020), (Fig. 1), prepared in ERDAS Imagine 16.5 (ERDAS Inc., 2018).

ERDAS Imagine 16.5 and the ArcGIS 10.5 (ESRI, 2017) software were used as the main packages for analyzing, processing and producing maps (landforms, soils, and land suitability classes).

Concerning the conventional grid system of soil survey, a total of 185 soil profiles have been examined and pedomorpholgically described (FAO, 2006) and sampled. The collected soil samples from genetic horizons / layers of the profile pits have been subjected to some physical and chemical determinations (USDA Soil Survey Staff, 2014b). Soil characteristics values were calculated by using weighting factors for the different profile sections (Sys *et al*., 1991a).

Soil classification has been carried out according to the norms of the USDA Soil Taxonomy (USDA Soil Survey Staff, 2014a).

Soil suitability assessment for certain crops (annuals and perennials has been conducted using ALMAGRA model constituent of Micro LEIS DSS (De la Rosa *et al.*, 2004), that is available to run at http://evenor-tech.com/microleis/microlei/microlei.aspx.

- Ten land use types were tested for suitability in the study area, namely: wheat (T), maize (M), melon (Me), potato (P), soybean (S), sunflower (G) and sugar beet (R) as annuals; and peach (Pe), citrus fruits (C) and olive (O) as perennials.
- The tested crops were chosen on basis that several problems facing the decision makers which are: low quality soil resources, shortage of available irrigation water and low quality of the available water.
- ALMAGRA model fits the types of biophysical evaluation that use the soil characteristics or conditions favorable for crop development in function of productivity as diagnostic criteria. The soil characteristics considered in this model are: limit of useful depth, stoniness, texture, drainage, carbonates content, salinity, sodium saturation, and degree of development of the profile. For each soil characteristic, there has been a gradation matrix which relates the soil characteristic value with the corresponding soil crop requirements. Following the procedure of maximum limitation, the five relative suitability classes for each crop have been determined: Class S1-Highly suitable, Class S2-Suitable, Class S3-Moderately suitable, Class S4-Marginally suitable, and Class S5- Not suitable. The subclasses are indicated by the letters corresponding to the main limiting soil diagnostic criteria.

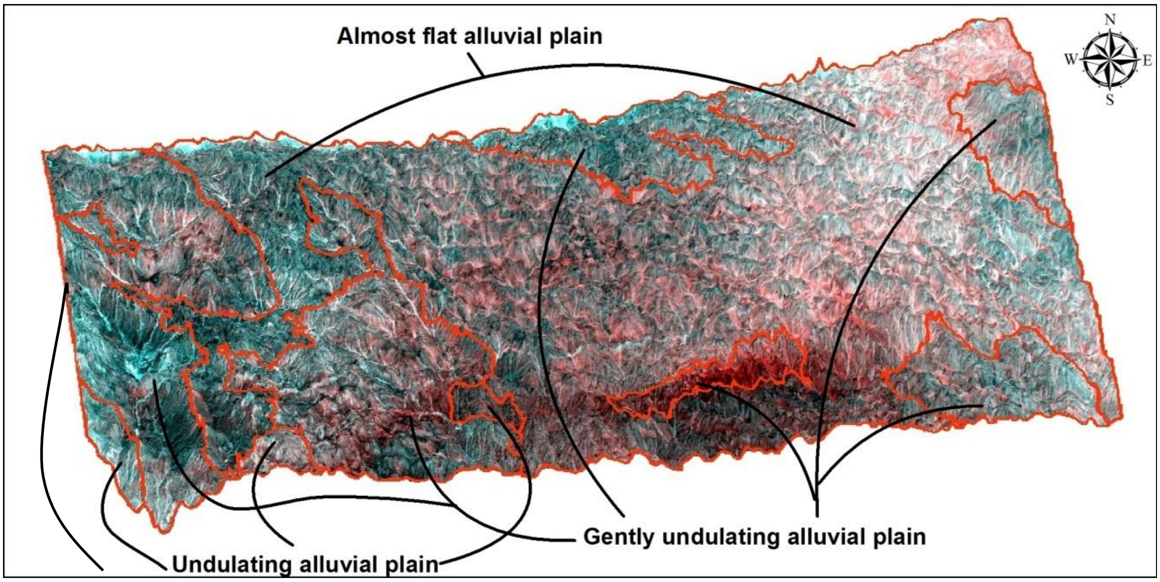


Fig. 1. 3D view of the study area showing the main landforms.

RESULTS AND DISCUSSION

The visual and digital interpretation of merged DEM with Sentinel 2A-MSI image is considered of a prime importance in distinguishing the common land scape units and their related soil units as well.

A- Land forms

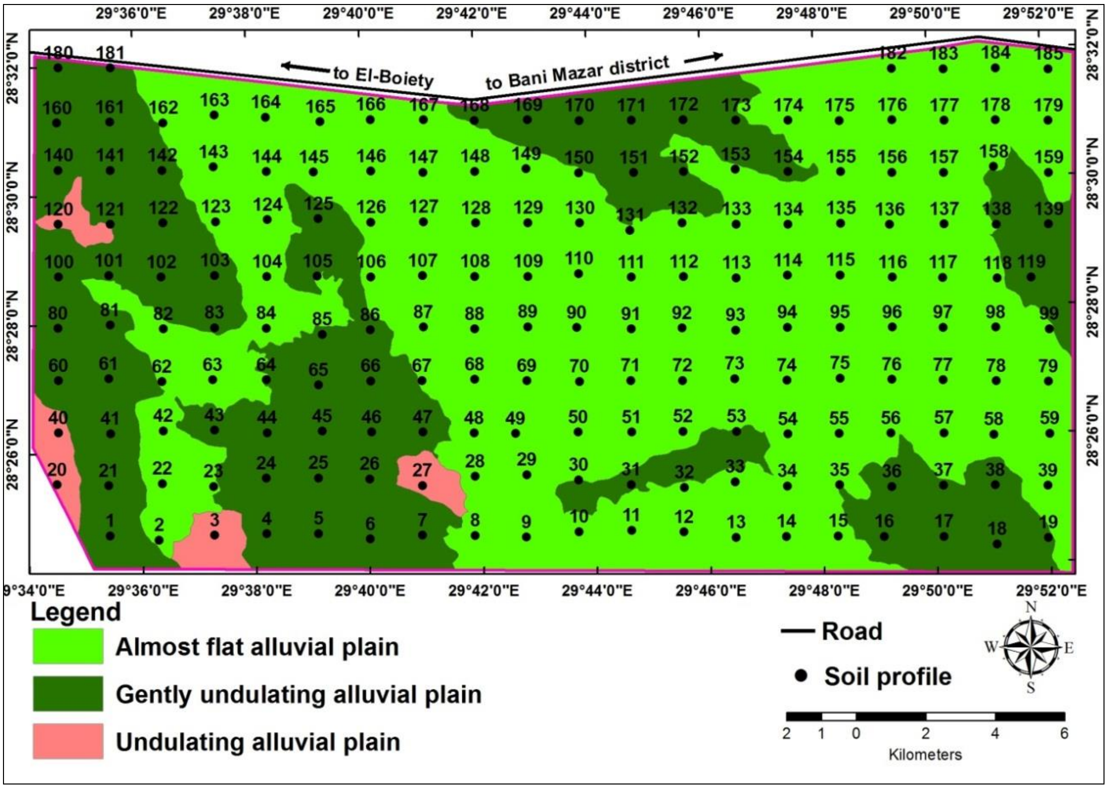
According to the geological map by EGPC - Conco Coral Staff (1987), topographic map and ground truth, it is fairly well denoted that, the study area falls within a broad band formed mainly of sand and gravels deposits of fluvial or estuarine origin, known as gravelly plain (Shata and Shata, 1999; Abu Al Izz, 2000).

The main land forms have been identified in terms of the geopedological approach (Zinck, 1989), map (2). Table (1) illustrates the proportions of each landscape unit, pinpointing that the almost flat alluvial plain is the most extensive outnumbering the areas those gently undulating alluvial plain by a proportion of two to one.

Table 1. Physiographic legend and proportions of each landform in the study area.

Landscape	Lithology / Origin	Topography*	Landform	Mapping unit code	Elev. (m)	Area (feddan)	Area (%)
Alluvial Plain (P)	Oligocene (O)	Almost flat 0.5 - 2% (A)	Almost flat alluvial plain	POA	111 - 130	64211	63.68
		Gently undulating 2-5% (G)	Gently undulating alluvial plain.	POG	120 - 150	34348	34.06
		Undulating 5-10% (U)	Undulating alluvial plain.	POU	145 - 167	2282	2.26
Total						100841	100

* The topography indicated by the first letter as A: Almost flat, G: Gently undulating, U: Undulating.

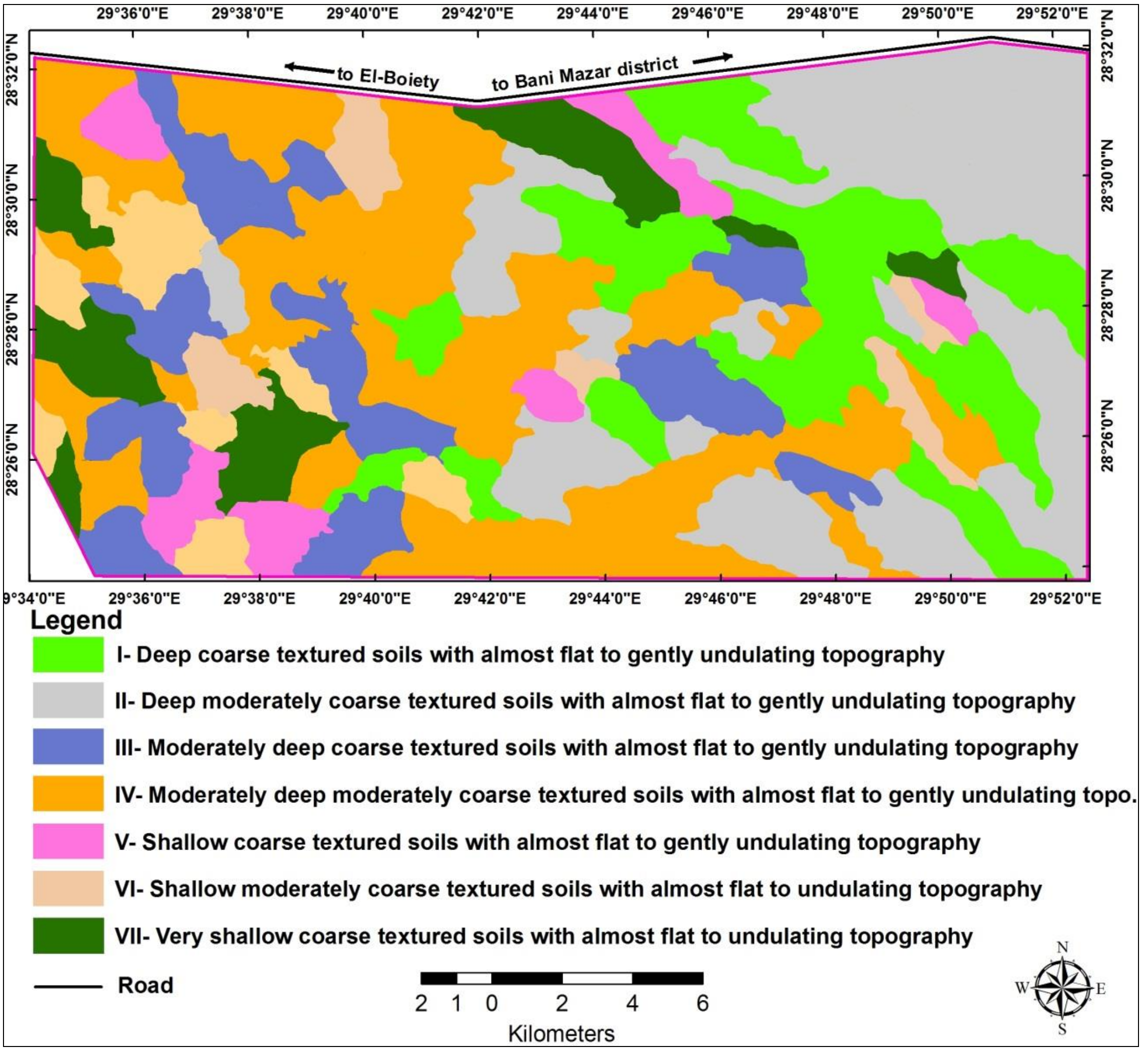


Map 2. Main landforms and the representative soil profiles of the study area.

B- Soil characteristics and classification

The information gained from remote sensing, GIS facilities, field work as well as some physical and chemical soils' attributes indicated the prevalence of particular soil types associated with the predominating landscape units, previously mentioned.

It is perceptible that the spatial distribution pattern of soil units (Map 3) takes a general longitudinal shape with North West – South East orientation; therein the coarse-textured soils alternate with the moderately coarse-textured ones. In addition, almost the land is covered with desert pavement and the deep soils are more immense in the eastern sector of the study area, whereas those having the limited root zone concentrate in the far western and south western portions. It is palpable that the moderately deep, moderately coarse-textured soils, with "almost flat" to "gently undulating" topography are the most predominating soil unit mostly occupying the middle part of the area (about 27.41% of the study area), followed by the deep moderately coarse textured soils with almost flat to gently undulating topography with about 23.88% of the total area as indicated in table (2).



Map 3. Soil mapping units of the study area.

Table (3) shows results of the main morphological features, physical and chemical characteristics of some representative soil profiles of the study area. The following presentation is a general outline of the general soil characteristics of the predominating soils.

1- The coarse - textured soils

These soils are dominated by loamy sand topsoil underlain by sandy layers. In some cases, in moderately deep soils, in particular, gravel content is rather high but less than 30 % in most layers (profile 82, 123 and 132). These soils are mostly covered with various-sized gravel. The relief ranges between almost flat and rather gently undulating. Soils are generally yellow (10YR 7/6, dry) and brownish yellow (10YR 6/6, moist), having soft to slightly hard topsoil and hard subsoil. Soils range between excessive and moderately well drainage classes.

The soils lack of any features related to the secondary formations, mostly due to the nature of the soil parent materials and also the prevailing arid climatic condition, which is associated with active wind erosion and deposition impacts.

In terms of the USDA Soil Taxonomy (USDA Soil Survey Staff, 2014a) and based on soil depth, three soil sub group could be defined as follow; (Map 4) and as represented in table (2).

The deep and moderately deep soils could be placed to *Typic Torripsamments*,

The shallow soils could be classified as *Lithic Torripsamments*, and

The very shallow soils belong to *Lithic Torriorthents*.

2- The moderately coarse - textured soils

These soils cover about 59.2% of the total area, where landscape ranges from almost flat to gently undulating. Concerning the morpho-pedolgical features, these soils could be distinguished into two groups, namely;

2-1 Soils without any recognizable secondary formations

2-2 Soils showing evidence of secondary formations

2-1 Soils without any recognizable secondary formations

Both the deep and moderately deep soils are generally brownish yellow (dry) changing into yellowish brown (moist), formed of sandy loam topsoil which gets coarser in subsoil layers e.g loamy sand, sand or gravelly sand.

Taxonomically, these soils belong to *Typic Torriorthents*. And very limited area (about 2.2% of the total area) has shallow soils (< 50 cm depth), therefore placed to *Lithic Torriorthents* at sub-group level.

2-2 Soils showing evidence of **secondary formations**

The soils represent about 50% of the total area. The most prominent feature of these soils is the polygonal thin surface cracks filled with drift sediments. This feature accompanies with the soil enrichment of gypsum, accumulating in different form, i.e soft and hard aggregates, mycelium, patches and/or crystals.

Table 2. Soil mapping units and their classification of the study area.

Soil Mapping Units Description	Description and code of Soil Sub Mapping Unit	Soil Taxa	Representative soil profiles No's.	Area (feddan)	Area (%)
1- Deep coarse textured soils with almost flat to gently undulating topography	Deep coarse textured soils with almost flat topography (A11)	*Typic Torripsamments*	51, 95, 132	16465	16.33
	Deep coarse textured soils with gently undulating topography (G11)		173		
2- Deep moderately coarse-textured soils with almost flat to gently undulating topography	Deep moderately coarse textured soils with almost flat topography (A12)	*Typic Haplogypsids*	90, 129, 156, 184	24079	23.88
		Typic Calcigypsids	52		
		Typic Torriorthents	96, 185		
	Deep moderately coarse textured soils with gently undulating topography (G12)	*Typic Haplogypsids*	139		
		Typic Calcigypsids	17		
		Typic Torriorthents	103		

Table 2. Cont.

Soil Mapping Units Description	Description and code of Soil Sub Mapping Unit	Soil Taxa	Representative soil profiles No's.	Area	
				(feddan)	(%)
3- Moderately deep coarse-textured soils with almost flat to gently undulating topography	Mod. deep coarse textured soils with almost flat topography (A21)	*Typic Torripsamments*	82, 123	12674	12.57
	Mod. deep coarse textured soils with gently undulating topography (G21)		85		
4- Moderately deep moderately coarse-textured soils with almost flat to gently undulating topography	Mod. deep moderately coarse textured soils with almost flat topography (A22)	*Typic Haplogypsids*	8, 68, 126, 148	27639	27.41
		Typic Calcigypsids	89		
		Typic Torriorthents	109		
	Mod. deep moderately coarse textured soils with gently undulating topography (G22)	*Typic Haplogypsids*	30, 181		
5- Shallow coarse-textured soils with almost flat to gently undulating topography	Shallow coarse textured soils with almost flat topography (A31)	*Lithic Torripsamments*	97	4776	4.74
	Shallow coarse textured soils with gently undulating topography (G31)		171		
6- Shallow moderately coarse-textured soils with almost flat to undulating topography	Shallow moderately coarse textured soils with almost flat topography (A32)	*Lithic Haplogypsids*	116	7980	7.91
		Lithic Torriorthents	166		
	Shallow moderately coarse textured soils with gently undulating topography (G32)	*Lithic Haplogypsids*	121		
		Lithic Torriorthents	122		
	Shallow moderately coarse textured soils with undulating topography (U32)	*Lithic Haplogypsids*	40		
7- Very shallow coarse- textured soils with almost flat to undulating topography	Very shallow coarse textured soils with almost flat topography (A41)	*Lithic Torriorthents*	133	7228	7.17
	Very shallow coarse textured soils with gently undulating topography (G41)		45, 140		
	Very shallow coarse textured soils with undulating topography (U41)		120		
Total				100841	100

Table 3. The main morphological feature, physical and chemical soil characteristics of representative soil profiles of the study area.

Profile No.	Lat. N Long. E	Drainage*	Depth (cm)	Soil colour Hue	Dry	Moist	Gravel (%)	Texture class**	Consistency***	pH	EC_{SE}**** dS/m	$CaCO_3$ (%)	Gypsum (%)	ESP
Soil mapping unit (1) Deep coarse-textured soils with almost flat to gently undulating topography														
Typic Torripsamments														
51	28°26'8" 29°44'39"	E	0-20	10YR	7/6	6/6	3.49	LS	SO	7.49	1.61	10.5	0.5	10.60
			25-50	7.5YR	7/6	6/6	23.39	GrLS	SHA	8.39	0.35	10.3	1.2	4.50
			50-80	7.5YR	7/6	6/6	20.38	GrLS	SHA	8.05	2.69	16.3	3.2	8.60
			80-110	7.5YR	6/8	5/8	34.46	GrS	HA	7.54	6.35	14.2	1.1	9.70
95	28°27'41" 29°48'22"	E	0-40	10YR	7/4	6/4	0.00	LS	SO	7.99	1.20	3.2	0.0	2.50
			40-70	10YR	7/6	5/6	3.85	S	LO	7.70	0.97	5.8	0.0	2.30
			70-120	10YR	7/6	5/6	1.54	S	SO	7.77	2.29	5.3	0.0	2.50
132	28°29'22" 29°45'37"	E	0-30	10YR	7/6	6/6	0.91	LS	SO	8.20	0.35	7.5	0.0	3.90
			30-75	7.5YR	6/8	5/8	34.00	GrS	SHA	8.30	2.24	2.1	0.0	4.20
			75-110	5YR	5/8	4/6	29.00	GrS	HA	8.20	2.54	1.4	0.0	8.50
173	28°30'57" 29°46'36"	E	0-35	10YR	7/6	6/6	3.41	LS	SO	8.20	2.38	7.5	0.0	3.50
			35-70	7.5YR	7/6	6/6	2.10	LS	SHA	8.39	6.43	3.0	2.1	6.70
			70-110	7.5YR	7/6	6/6	1.00	S	HA	8.10	2.61	5.5	2.3	8.10
Soil mapping unit (2) Deep moderately coarse-textured soils with almost flat to gently undulating topography Soil														
Typic Haplogypsids														
90	28°27'47" 29°43'43"	W	0-30	10YR	7/6	5/6	2.50	SL	SO	7.68	8.85	7.5	1.1	5.80
			30-60	7.5YR	8/4	7/4	3.33	SL	SHA	8.22	16.75	8.3	7.2	10.70
			60-105	10YR	7/4	6/4	25.00	LS	HA	7.89	2.85	25.5	6.3	11.60
129	28°29'25" 29°42'54"	W	0-30	10YR	7/6	6/6	9.26	LS	SO	8.70	1.78	12.3	0.5	4.80
			30-60	7.5YR	7/6	6/6	23.00	GrS	SHA	8.61	7.85	13.2	4.2	13.50
			60-105	7.5YR	6/6	5/6	18.00	GrS	HA	8.20	18.56	19.5	5.5	15.90
139	28°29'13" 29°52'5"	W	0-30	10YR	7/6	6/6	3.25	SL	SO	8.35	5.89	10.4	0.0	9.50
			30-60	10YR	7/6	6/6	15.00	SL	SHA	8.26	4.81	8.8	6.1	7.50
			60-105	10YR	7/6	6/6	1.82	SL	HA	8.21	18.72	29.3	1.2	15.10
156	28°30'5" 29°49'20"	W	0-20	10YR	7/6	5/6	1.81	SL	SO	8.03	3.91	6.5	0.0	3.50
			20-50	7.5YR	6/8	4/6	20.73	GrS	SHA	7.91	4.12	7.5	8.2	6.60
			50-105	7.5YR	6/8	4/6	17.65	GrL	HA	7.76	2.42	18.7	3.3	8.10
184	28°31'40" 29°51'12"	W	0-40	7.5YR	7/6	6/6	2.14	SL	SO	7.90	2.60	4.5	0.0	6.20
			40-80	7.5YR	7/6	6/6	4.50	SL	SHA	8.10	3.40	6.8	7.5	7.30
			80-110	7.5YR	7/6	6/6	3.90	S	HA	8.20	2.30	10.4	4.8	6.40
Typic Calcigypsids														
17	28°24'24" 29°50'6"	W	0-20	7.5YR	7/4	6/4	5.56	SL	SO	7.90	1.05	10.0	0.0	7.42
			20-60	7.5YR	7/4	6/4	13.64	SL	SO	8.30	2.63	7.8	5.1	9.37
			60-90	7.5YR	8/4	7/4	28.57	SL	SHA	8.40	5.96	27.2	3.2	9.75
			90-130	7.5YR	8/4	7/4	0.00	LS	HA	7.79	4.69	20.0	1.1	8.65
52	28°26'7" 29°45'33"	W	0-15	10YR	7/6	6/6	2.88	SL	SO	7.76	2.66	15.0	1.1	5.60
			15-40	10YR	7/6	6/6	0.83	SL	SHA	7.87	4.66	13.2	3.2	10.60
			40-80	7.5YR	7/6	6/6	0.00	SL	SHA	7.67	9.34	18.2	6.1	11.80
			80-120	7.5YR	6/8	5/8	0.00	LS	HA	7.74	11.5	13.2	4.2	11.50

Table 3. Cont.

Profile No.	Lat. N Long. E	Drainage*	Depth (cm)	Soil colour			Gravel (%)	Texture class**	Consistency***	pH	EC_{SE}**** dS/m	$CaCO_3$ (%)	Gypsum (%)	ESP
Typic Torriorthents														
96	28°27'40" 29°49'17"	W	0-20	10YR	7/6	5/6	0.00	SL	SO	7.67	6.20	9.0	1.1	5.40
			20-65	10YR	7/6	5/6	3.64	SL	SHA	8.15	9.10	16.3	4.3	9.90
			65-105	10YR	8/4	7/4	1.41	LS	HA	7.85	2.58	10.5	4.2	5.80
103	28°28'43" 29°37'22"	W	0-25	7.5YR	7/6	6/6	2.50	SL	SO	8.60	3.93	8.3	0.0	4.10
			25-60	7.5YR	7/6	6/6	26.67	GrSL	SHA	8.45	7.26	8.3	3.3	6.30
			60-105	5YR	6/8	5/8	26.25	GrLS	HA	8.00	9.32	16.5	1.2	9.00
185	28°31'38" 29°52'8"	W	0-15	7.5YR	7/6	6/6	3.13	LS	SO	8.10	2.50	12.2	0.0	4.90
			15-40	7.5YR	7/6	6/6	0.00	SL	SHA	7.80	3.40	1.5	3.9	5.30
			40-115	7.5YR	7/6	6/6	0.71	SL	HA	7.90	3.20	4.0	4.8	5.40
Soil mapping unit (3) Moderately deep coarse-textured soils with almost flat to gently undulating topography														
Typic Torripsamments														
82	28°27'54" 29°36'26"	MW	0-20	10YR	7/6	5/6	32.96	GrLS	SHA	7.74	4.95	8.8	0.0	4.60
			20-60	7.5YR	6/6	5/6	29.15	GrS	HA	7.11	3.60	9.1	0.0	7.20
			60-80	7.5YR	6/6	5/6	16.67	S	HA	7.44	1.49	8.3	0.0	8.20
85	28°27'46" 29°39'14"	MW	0-20	7.5YR	7/6	5/6	3.13	LS	SO	7.65	6.80	3.3	1.1	7.30
			20-50	7.5YR	7/6	5/6	23.81	GrS	SHA	7.74	12.00	1.6	3.2	9.70
			50-70	7.5YR	6/6	5/6	26.67	GrS	HA	7.68	16.00	10.7	3.1	13.50
			70-90	7.5YR	6/6	5/6	28.15	GrS	HA	7.47	2.60	8.8	2.4	4.60
123	28°29'33" 29°37'24"	MW	0-20	10YR	7/6	6/6	20.63	GrLS	SO	8.51	2.42	9.0	0.0	8.30
			20-35	7.5YR	7/6	6/6	31.58	GrS	SO	8.70	2.69	10.7	2.1	5.20
			35-80	7.5YR	6/8	5/8	34.89	GrS	HA	8.30	6.01	18.6	2.2	8.90
Soil mapping unit (4) Moderately deep moderately coarse-textured soils with almost flat to gently undulating														
Typic Haplogypsids														
8	28°24'35" 29°41'51"	MW	0-25	10YR	7/8	6/8	2.14	SL	SO	8.07	2.10	10.8	0.0	7.70
			25-50	7.5YR	8/4	7/6	3.00	SL	HA	8.05	2.52	4.0	6.1	5.43
			50-75	7.5YR	6/6	5/6	8.33	S	HA	8.18	8.29	12.2	5.5	7.86
30	28°25'25" 29°43'42"	MW	0-30	10YR	7/6	6/6	3.08	SL	SO	8.19	2.12	12.0	1.1	5.76
			30-55	7.5YR	8/4	7/4	0.00	SL	VH	8.33	4.70	4.5	10.1	3.15
68	28°27'1" 29°41'54"	MW	0-30	7.5YR	7/6	5/6	1.67	SL	SO	8.06	2.47	6.7	0.0	3.20
			30-60	7.5YR	7/6	5/6	1.67	SL	SHA	7.65	6.35	11.3	6.2	7.90
126	28°29'29" 29°40'8"	MW	0-35	10YR	7/6	6/6	8.70	LS	SO	8.45	2.73	11.9	0.0	8.40
			35-60	7.5YR	7/4	6/4	8.33	SL	SHA	8.61	10.46	7.2	9.5	11.20
			60-85	7.5YR	7/6	6/6	8.33	SL	VH	8.00	27.45	15.8	4.1	14.10
148	28°30'14" 29°41'59"	MW	0-40	10YR	7/6	6/6	0.83	LS	SO	8.23	9.86	6.8	0.0	5.60
			40-65	7.5YR	7/6	6/6	1.54	SL	SHA	8.45	1.90	2.3	3.2	2.50
			65-90	7.5YR	6/8	5/8	16.36	SL	HA	8.67	7.85	10.5	7.1	8.50
181	28°31'59" 29°35'36"	MW	0-15	10YR	7/6	6/6	3.13	LS	SO	7.90	4.20	12.2	0.0	7.50
			15-40	10YR	7/6	6/6	0.00	SL	HA	8.10	3.60	1.5	10.2	5.90
			40-70	10YR	8/3	7/3	0.71	SL	HA	8.00	3.80	4.0	6.1	5.80

Table 3. Cont.

Profile No.	Lat. N Long. E	Drainage*	Depth (cm)	Soil colour			Gravel (%)	Texture class**	Consistency***	pH	EC_{SE}**** dS/m	$CaCO_3$ (%)	Gypsum (%)	ESP
							Typic Calcigypsids							
89	28°27'48" 29°42'52"	MW	0-30	10YR	7/6	5/6	7.50	LS	SO	7.76	2.92	10.7	0.0	4.50
			30-50	7.5YR	7/8	6/8	5.38	SL	SHA	7.87	3.85	26.2	4.9	11.60
			50-80	7.5YR	6/6	5/6	12.90	SL	HA	7.92	2.65	22.5	6.1	10.40
							Typic Torriorthents							
109	28°28'35" 29°42'53"	MW	0-30	10YR	7/6	6/6	0.83	LS	SO	8.70	1.44	10.5	0.0	4.20
			30-50	7.5YR	7/6	6/6	20.59	GrSL	SO	8.43	3.52	13.5	2.1	6.40
			50-90	7.5YR	7/6	6/6	13.79	SL	SHA	8.48	6.01	33.0	1.1	13.40
				Soil mapping unit (5) Shallow coarse textured soils with almost flat to gently undulating topography										
							Lithic Torripsamments							
97	28°27'39" 29°50'11"	P	0-45	7.5YR	7/4	6/4	14.52	LS	SO	7.70	1.85	4.9	3.1	3.30
171	28°30'59" 29°44'46"	P	0-40	10YR	7/6	6/6	2.00	S	SO	8.30	2.70	9.2	1.1	4.30
				Soil mapping unit (6) Shallow moderately coarse-textured soils with almost flat to undulating topography										
							Lithic Haplogypsids							
40	28°26'19" 29°34'33"	P	0-20	10YR	7/6	6/6	4.17	SL	SO	8.49	3.32	14.7	1.1	4.80
			20-45	7.5YR	8/4	7/4	5.00	SL	SHA	8.60	8.41	3.1	7.1	3.90
116	28°28'27" 29°49'18"	P	0-10	10YR	7/6	5/6	10.00	SL	SO	8.25	6.98	7.3	3.1	8.60
			10-35	7.5YR	7/4	7/4	0.74	SL	SHA	7.91	0.75	2.8	8.2	3.90
121	28°29'33" 29°35'32"	P	0-30	10YR	7/6	6/6	0.75	SL	SO	8.30	7.74	7.8	1.5	10.30
			30-50	10YR	8/4	7/4	0.00	SL	SHA	8.13	6.57	7.5	9.1	10.50
							Lithic Torriorthents							
122	28°29'33" 29°36'28"	P	0-10	10YR	7/6	6/6	0.63	SL	SO	8.60	2.17	8.2	1.1	5.80
			10-35	5YR	7/6	6/6	14.29	SL	HA	7.90	15.00	5.2	4.1	13.10
166	28°31'5" 29°40'10"	P	0-35	7.5YR	7/6	6/6	2.50	SL	SO	8.50	2.10	2.9	8.6	4.50

Table 3. Cont.

Profile No.	Lat. N Long. E	Drainage*	Depth (cm)	Soil colour			Gravel (%)	Texture class**	Consistency***	pH	EC_{SE}**** dS/m	$CaCO_3$ (%)	Gypsum (%)	ESP
Soil mapping unit (7) Very shallow coarse textured soils with almost flat to undulating topography														
Lithic Torriorthents														
45	28°26'15" 29°39'12"	VP	0-20	10YR	7/6	6/6	3.85	LS	SHA	8.26	2.42	22.5	2.2	11.40
120	28°29'34" 29°34'37"	VP	0-20	10YR	7/6	6/6	0.50	LS	SO	8.41	3.12	10.3	0.0	5.40
133	28°29'20" 29°46'34"	VP	0-15	10YR	7/6	6/6	3.57	LS	SO	8.50	1.20	10.5	0.0	9.50
140	28°30'24" 29°34'38"	VP	0-15	10YR	7/6	5/6	0.77	LS	SO	8.43	2.13	13.0	1.2	5.40

* Drainage: W - Well, MW - Moderately Well, E - Excessive, P - Poor, VP - Very poor.

**Texture: S - Sand, LS - Loamy Sand, SL - Sandy Loam, GrS - Gravelly Sand, GrLS - Gravelly Loamy Sand, GrSL - Gravelly Sandy Loam.

*** Consistency: LO - Loose, SO - Soft, SHA - Slightly Hard, HA - Hard, VHA - Very Hard.

**** EC_{SE}: EC measured in a saturated soil paste (FAO, 2006)

In many cases gypsum does not exist in the topsoil, but increase gradually with depth. These soils are calcareous where carbonate show different trends and rarely forming calcic horizon.

Accordingly, those soils could be distinguished into three different sub groups related to the order Aridisols which are;

- *Typic Haplogypsids* for deep and moderately deep, moderately coarse-textured soil having gypsic horizon.
- *Lithic Haplogypsids* for shallow, moderately coarse-textured soil having secondary gypsum formation.
- *Typic Calcigypsids* for soils covering a very limited area (around 1.62 % of the study area), having calcic horizon in association with the gypsic one.

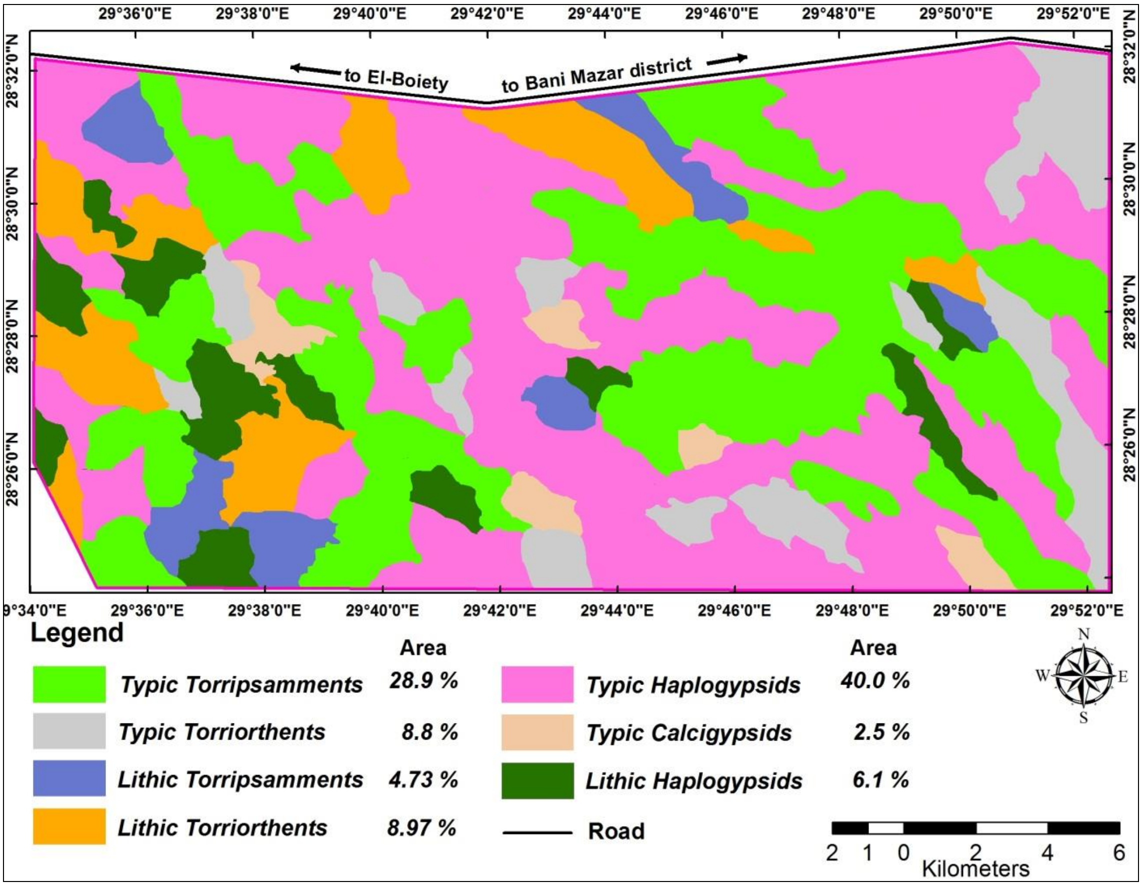
C- Land suitability for agricultural utilization

This approach could be accomplished through assessment of some unanimous soil attributes by ALMAGRA model constituent of MicroLEIS Decision Support System, (De la Rosa *et al*., 2004). Accordingly, the potential land use types, relevant to the prevailing conditions, could be determined via investigation of three perennial crops (Olive, peach and Citrus) and also seven annuals (Wheat, Maize, Melon, Potato, Soybean, Sunflower and Sugar beet).

Data in tables (4 and 5), demonstrated in maps (5, 6, 7 and 8) patently connote that, with respect to the study area, land suitability for the attempted crops fall under classes namely Suitable (S2), Moderately Suitable (S3), Marginally Suitable (S4), and Not Suitable (S5). The following is an account of that;

1- Deep, coarse-textured soils

These soils are classified at subgroup level as *Typic Torripsamments*, occupying an area of about 16465 feddans (16.33% from the total study area). They have been evaluated as suitable ($S2_{tdc}$) for Olive and moderately suitable ($S3_t$) for both of Peach and Citrus. As for annuals crops, they were evaluated as marginally suitable ($S4_t$). Noteworthy to specify that some rare cases, represented by soil profiles No. 26, 28 and 132, showed less suitability for Peach and Citrus that was $S4_t$, and not suitable for annual crops ($S5_t$).



Map 4. Soil classification of the study area.

2- Deep and moderately deep, moderately coarse-textured soils

These soils ordinarily belong to subgroup *Typic Haplogypsids*, *Typic Calcigypsids*, beside some limited areas belonging to *Typic Torriorthents.* This mapping unit occupies an area representing about 51.29% of the study area. The agricultural limitations are generally related to the excessive drainage and nutrients impoverishment. Soils are commonly classified as moderately suitable ($S3_t$) for the evaluated annual crops and suitable (S2) to moderately suitable (S3) for orchards. Nevertheless, in some limited area, represented by soil profiles No. 7, 14, 57, 84, 90, 103, 125, 137, 153, and 163, showed marginal suitability (S4) for some annual crops.

3- Moderately deep, coarse-textured soils

These soils belong to the sub group *Typic Torriorthent*s; covering an area of about 12674 feddans (12.57% of the total area). Agricultural limitations are related to the coarse texture, moderate rooting zone and dearth of nutrients. Soils are commonly evaluated as moderately suitable (S3) for orchards and marginally suitable (S4) for annual crops.

4- Shallow, coarse and moderately coarse soils

These soils represent about 12.65% of the total area, of which more than 50% belong to the subgroup *Lithic Haplogypsids*, 33% of which is *Lithic Torripsamments* and the rest is *Lithic Torriorthents*. These soils have got severe limitations; due to which they are evaluated as marginally suitable (S4) for all tested crops. Except for the shallow, moderately coarse-textured soils evaluated as moderately suitable (S3) for annual crops.

5- Very shallow coarse-textured soils

They are locally distributed in some limited sites, occupying around 7.17% of the total study area. They are classified as *Lithic Torriorthents*, having severe limitations related to the very shallow rooting zone, very poor drainage and high gravel content. These soils range from marginally suitable to not suitable for the tested annual crops. As for orchard, these soils are not suitable; therefore they are evaluated as S5.

Table 4. Suitability grades* for the selected land use types of soil mapping units at the study area.**

Profile No.	T	M	Me	P	S	G	R	Pe	C	O
Soil mapping unit (1) Deep coarse textured soils with almost flat to gently undulating topography										
18	S4t***	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
26	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
28	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
37	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
51	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
58	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
74	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
75	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
77	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
78	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
87	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
95	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
111	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
115	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
118	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
119	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
130	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
131	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
132	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
134	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
135	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
136	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
154	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
172	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
173	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
Soil mapping unit (2) Deep moderately coarse textured soils with almost flat to gently undulating topo.										
12	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
13	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
14	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S3t
16	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
17	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tca	S2tca	S2ta
19	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
29	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
33	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
34	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
36	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2ta	S2ta	S2tca
38	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
39	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
49	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
50	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
52	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
59	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
79	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs

Table 4. Cont.

Profile No.	T	M	Me	P	S	G	R	Pe	C	O
90	S4s	S4s	S4s	S4s	S4s	S4s	S3ts	S5s	S5s	S3s
93	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsg	S2tsg	S2tcs
96	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
98	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
99	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsg	S2tsg	S2tcs
103	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3ts
108	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsg	S2tsg	S2tcs
128	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
129	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
137	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S3t
138	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
139	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
149	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
150	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
153	S4s	S4s	S4s	S4s	S4s	S4s	S3ts	S5s	S5s	S3s
155	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
156	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
157	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
158	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
159	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2ts
174	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
175	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsg	S2tsg	S2tcs
176	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
177	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
178	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
179	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tcs	S2tcs	S2tsa
182	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tag	S2tag	S2tca
183	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
184	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tsa	S2tsa	S2tcs
185	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tg	S2tg	S2tc
Soil mapping unit (3) Moderately deep coarse textured soils with almost flat to gently undulating topo.										
1	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
5	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4s	S4s	S3s
6	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4s	S4s	S3s
22	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
35	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
41	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
42	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2td
46	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
47	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
71	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
72	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
73	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2ptd

Table 4. Cont.

Profile No.	T	M	Me	P	S	G	R	Pe	C	O
82	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
83	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
85	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5s	S5s	S3ts
105	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
113	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
114	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
123	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
124	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4ts	S4ts	S3ts
143	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2ptd
145	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tda
162	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S2tdc
Soil mapping unit (4) Moderately deep moderately coarse textured soils with almost flat to gently undulating topography										
7	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S3t
8	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
9	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
10	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
11	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tda	S2tda	S2tdc
15	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
21	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
25	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
30	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
31	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
32	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
48	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
53	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
54	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
55	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
56	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
57	S4s	S4s	S4s	S4s	S4s	S4s	S3ts	S5s	S5s	S3s
60	S3t	S3ta	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
62	S3ts	S3ts	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
66	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
67	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tda
68	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
84	S4ts	S4ts	S4ts	S4ts	S4ts	S4ts	S4t	S5s	S5s	S3ts
86	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
88	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
89	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
91	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
92	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s

Table 4. Cont.

Profile No.	T	M	Me	P	S	G	R	Pe	C	O
94	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
101	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3ts
104	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
106	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
107	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
109	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tda
110	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
112	S3t	S3t	S3ts	S3t	S3t	S3t	S3t	S3s	S3s	S3s
125	S4s	S4s	S4s	S4s	S4s	S4s	S3ts	S5s	S5s	S3s
126	S3ts	S3tsa	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
127	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tda	S2tda	S2tdc
141	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
142	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
144	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
147	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
148	S3ts	S3ts	S3ts	S3ts	S3ts	S3ts	S3t	S4s	S4s	S3s
160	S3t	S3ta	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
163	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3t	S3t	S3t
164	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
165	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2ptd	S2ptd	S2ptd
167	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tdc	S2tdc	S2tds
180	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tda	S2tda	S2tdc
181	S3t	S3t	S3t	S3t	S3t	S3t	S3t	S2tds	S2tds	S2tdc
Soil mapping unit (5) Shallow coarse textured soils with almost flat to gently undulating topography										
2	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4pd	S4pd	S4d
4	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4pd	S4pd	S4d
23	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4pd	S4pd	S4d
69	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4pd	S4pd	S4d
97	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4d	S4d	S4d
152	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4pd	S4pd	S4d
161	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4td	S4td	S4d
171	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4d	S4d	S4d
Soil mapping unit (6) Shallow moderately coarse textured soils with almost flat to undulating topo.										
3	S3td	S3t	S3t	S3t	S3td	S3t	S3td	S4d	S4d	S4d
27	S3td	S3t	S3ts	S3t	S3td	S3t	S3td	S4d	S4d	S4d
40	S3td	S3t	S3ts	S3t	S3td	S3t	S3td	S4d	S4d	S4d
43	S3td	S3t	S3t	S3t	S3td	S3t	S3td	S4d	S4d	S4d
63	S3ptd	S3pts	S3pts	S3pts	S3ptd	S3pts	S3ptd	S4pds	S4pds	S4d
64	S3ptd	S3pts	S3pts	S3pts	S3ptd	S3pts	S3ptd	S4pds	S4pds	S4d
65	S3td	S3t	S3t	S3t	S3td	S3t	S3td	S4d	S4d	S4d

Table 4. Cont.

Profile No.	T	M	Me	P	S	G	R	Pe	C	O
70	S3td	S3t	S3t	S3t	S3td	S3t	S3td	S4d	S4d	S4d
76	S3td	S3ta	S3ts	S3t	S3td	S3t	S3td	S4d	S4d	S4d
100	S3td	S3tca	S3tcs	S3tc	S3td	S3t	S3td	S4d	S4d	S4d
102	S3tds	S3ts	S3ts	S3ts	S3tds	S3ts	S3td	S4ds	S4ds	S4d
116	S3ptd	S3pt	S3pt	S3pt	S3ptd	S3pt	S3ptd	S4pd	S4pd	S4d
121	S3tds	S3ts	S3ts	S3ts	S3tds	S3ts	S3td	S4ds	S4ds	S4d
122	S3ptd	S3pts	S3pts	S3pts	S3ptd	S3pts	S3ptd	S4pds	S4pds	S4d
146	S3ptd	S3pt	S3pt	S3pt	S3ptd	S3pt	S3ptd	S4pd	S4pd	S4d
166	S3ptd	S3pt	S3pt	S3pt	S3ptd	S3pt	S3ptd	S4pd	S4pd	S4d
Soil mapping unit (7) Very shallow coarse textured soils with almost flat to undulating topography										
20	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
24	S4ptd	S5p	S5p	S4pt	S5p	S4pt	S4ptd	S5pd	S5pd	S5d
44	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
45	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
61	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5pd	S5pd	S5d
80	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
81	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
117	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5t	S5pds	S5pds	S5ds
120	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
133	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
140	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
151	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
168	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
169	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d
170	S4ptd	S4pt	S4pt	S4pt	S4ptd	S4pt	S4ptd	S5pd	S5pd	S5d

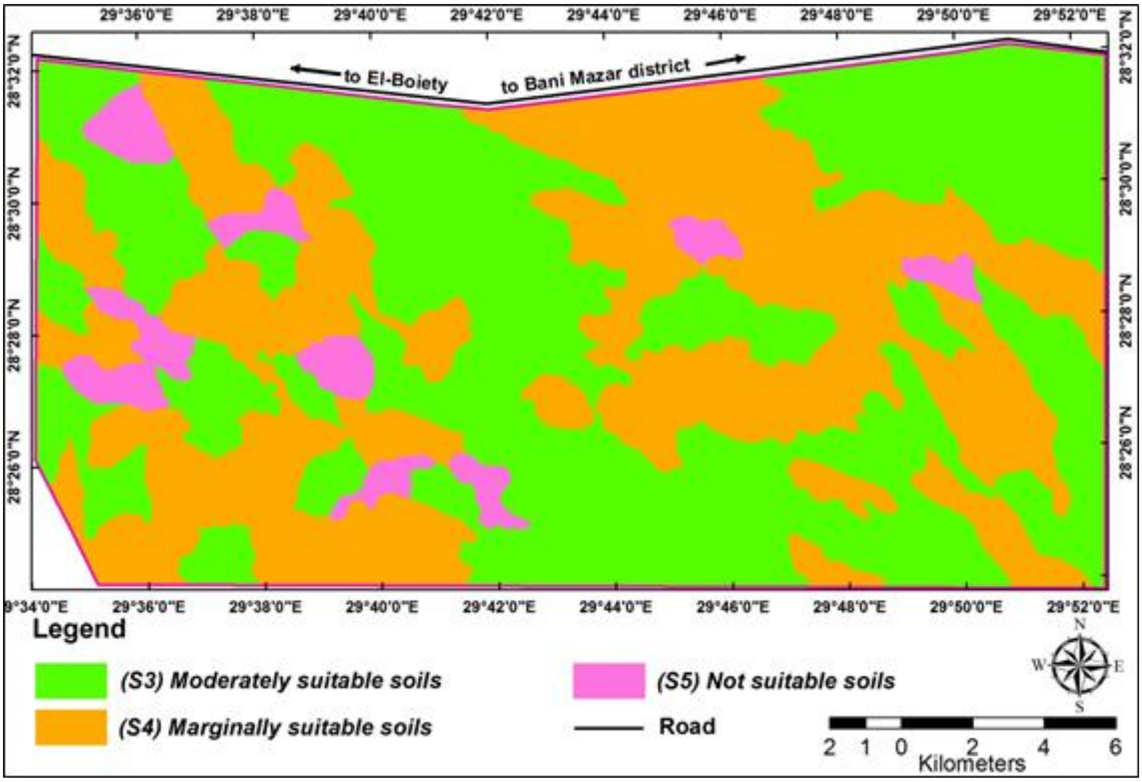
* Suitability grades: (S1) Highly suitable soils, – (S2) Suitable soils, – (S3) Moderately suitable soils, – (S4) Marginally suitable soils – (S5) Not suitable soils

** land use types: (T) wheat, - (M) maize, - (Me) melon, - (P) potato, - (S) soybean, -(G) sunflower, - (R) sugar beet, - (Pe) peach, (C) citrus fruits, - (O) olive

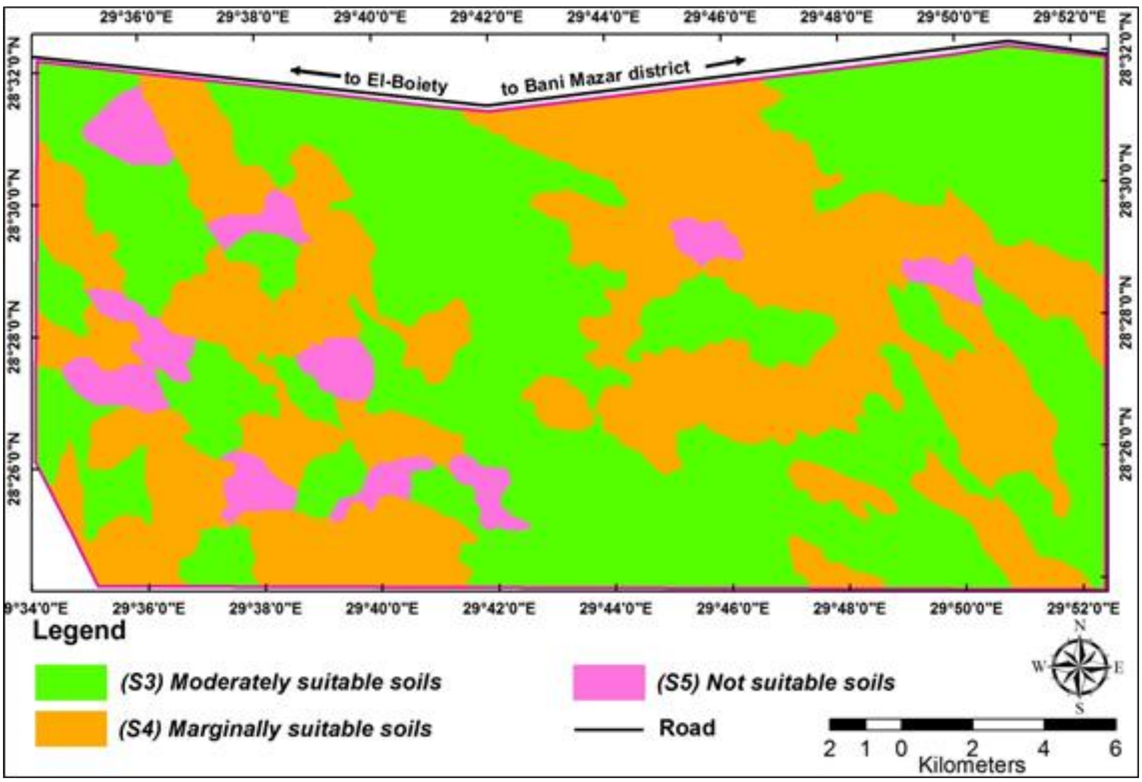
*** Soil limitations: (p) Useful depth - (t) Texture - (d) Drainage condition - (c) Carbonates content - (s) Salinity - (a) Sodium saturation – (g) Profile development

Table 5. Suitability classes for the selected land uses and their areas (feddan) in the study area.

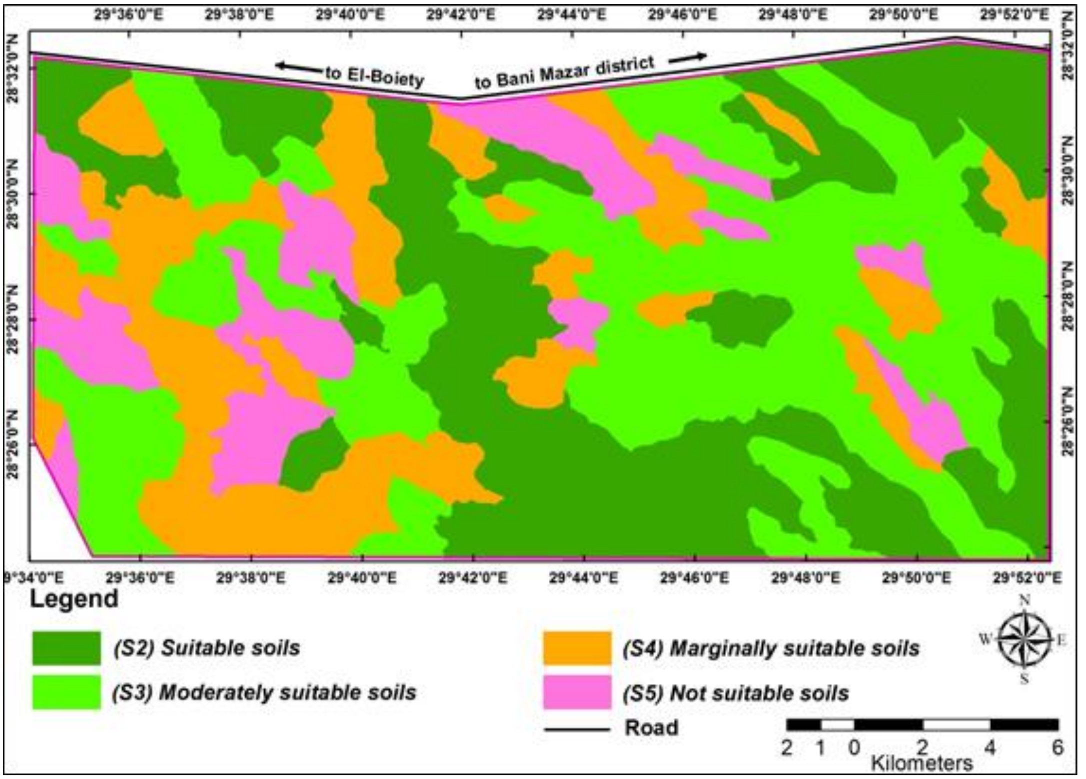
Suitabi-lity grades	Land use									
	T	M	Me	P	S	G	R	Pe	C	O
S2	-	-	-	-	-	-	-	32318	32318	54012
S3	52657	52657	52657	52657	52657	52657	52657	36179	36179	26845
S4	42873	42254	42254	42873	42254	42873	42873	20526	20526	12756
S5	5311	5930	5930	5311	5930	5311	5311	11818	11818	7228
Main limitati-ons	t, p, d	t, a	t, s	t, p, s	t, d, s	t, s, p	t, d, p	t, s, a	t, s, a	T, d, c
Total	100841 feddan each crop									



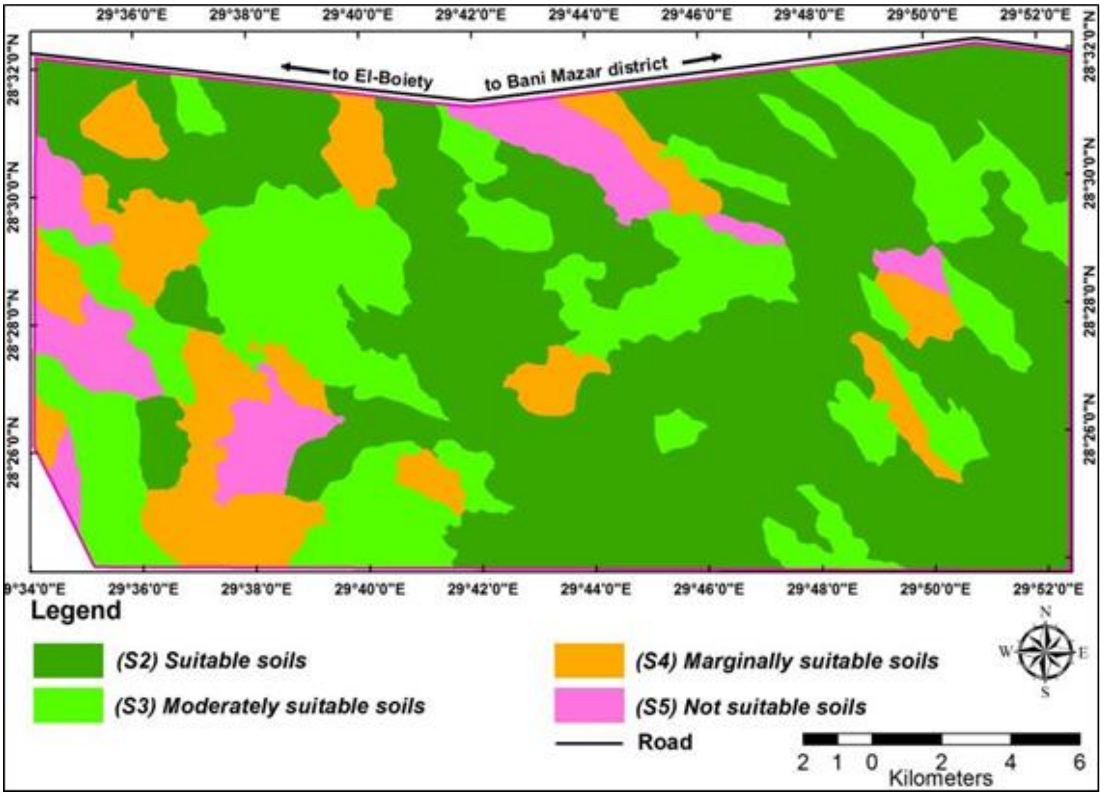
Map 5. Soil suitability classification for wheat, potato, sunflower and sugar beet of the study area.



Map 6. Soil suitability classification for maize, melon, and soybean of the study area.



Map 7. Soil suitability classification for peach and citrus of the study area.



Map 8. Soil suitability classification for olive of the study area.

D- A proposal for optimal crop alternatives land use

Data in table (6) and maps (9 &10) display the proposal of the possible options of the crop alternatives land use for the study area. Regarding the perennial crops, an area of about 32318 feddans was found, belonging to the class S2 (Suitable), preferable for cultivating Citrus and/or Peach. In addition, an area of about 21694 feddans is considered to be grown only with Olive crop.

With respect to the annual crops, Wheat and Maize have got a conspicuous to be grown by economic importance at the national level. Therefore, they have a great priority to be grown particularly within soils classified as moderately suitable (S3) for most annuals crops tested; accounting for about 26845 feddans.

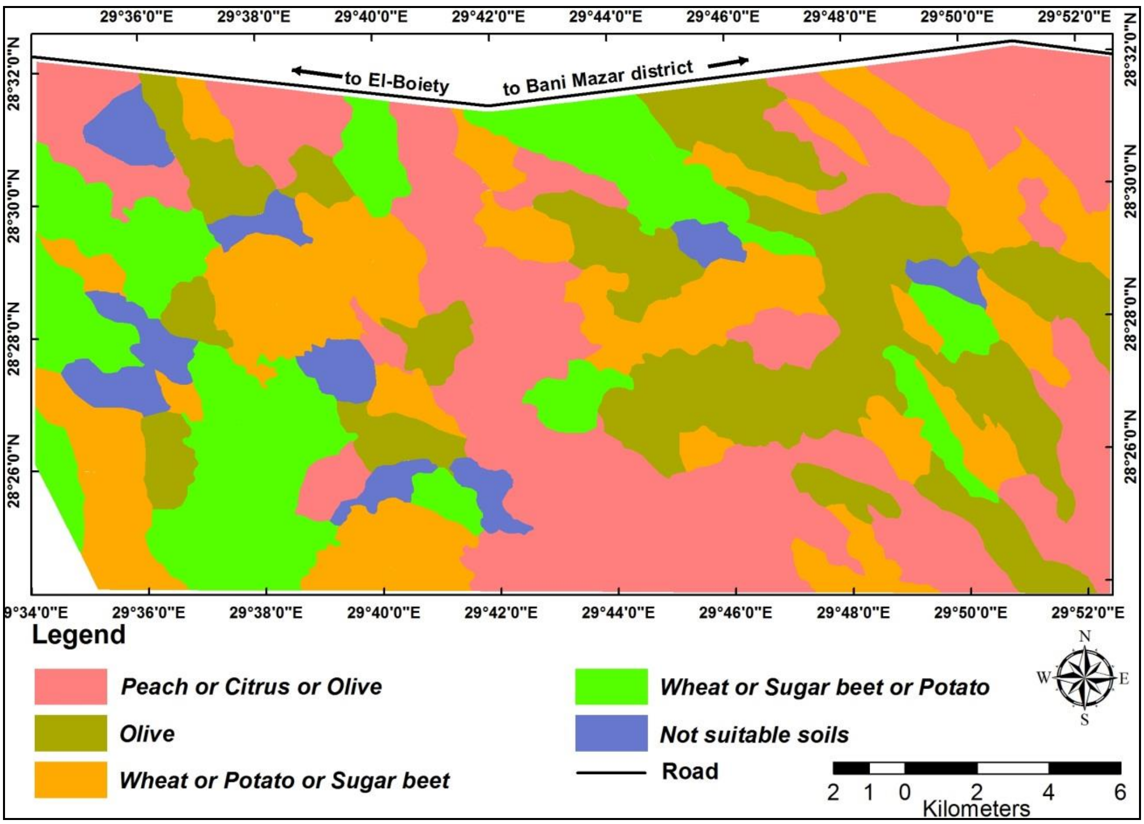
Some vegetable crops can be intercropped within orchard trees during the first five years of orchard plantation, in addition to about 14673 feddans estimated as marginally suitable for vegetable crops. It is indicated that around 5311 feddans (5.26 % of the total study area) are classified under the class (not suitable) for any tested crops.

Prospective research work should be projected towards testing the suitability of the different soils for a rather wide range of crop types including orchards (date palm, fig, almond etc..); field and forage crop (barley, forage beet, canola, broad bean etc..); vegetables (tomato, eggplant, cabbage, table beet etc..) and medicinal and aromatic plants (thyme, mint, moringa, jojoba etc..). Windbreaks (acacia, cypress, camphor or casuarina) are recommended to alleviate erosion hazards.

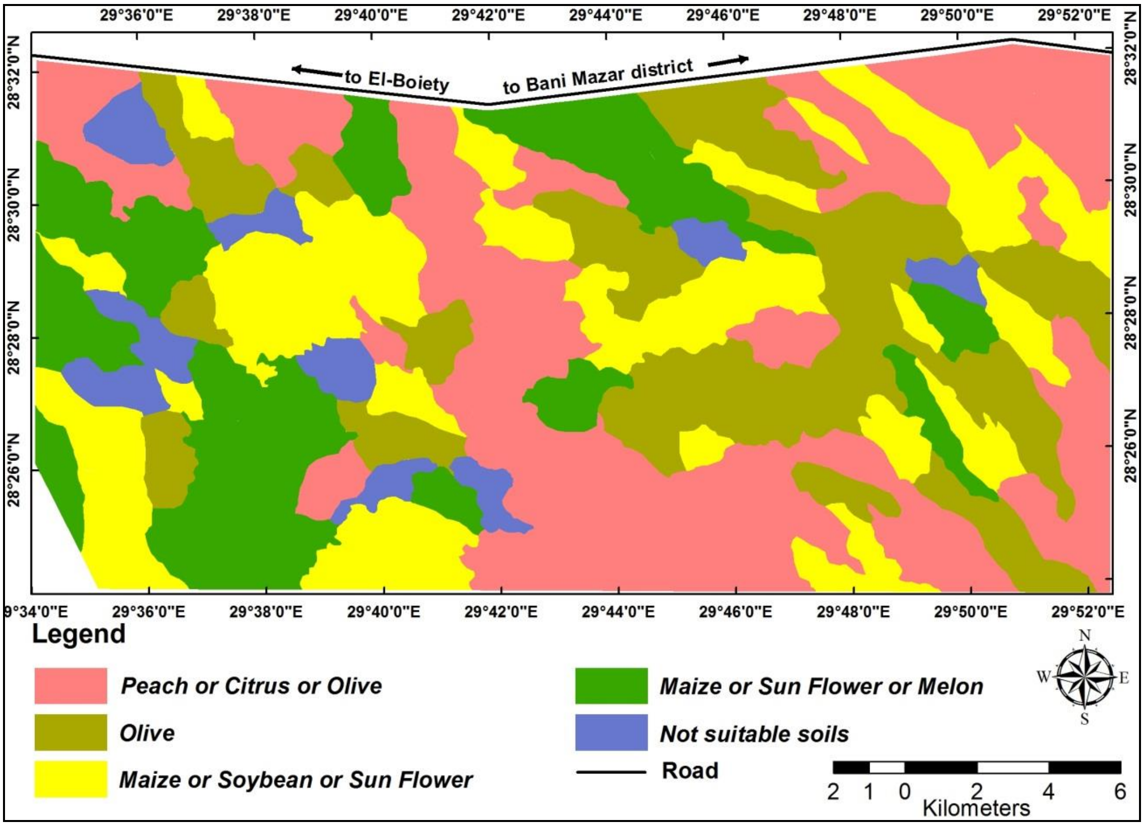
E- Sustainable agriculture management

Acquiring an appropriate management of sustainable agriculture, by running flexible business and farming practices, needs giving the fragility of the desert environment a considerable importance.

In view of the harsh environment for natural vegetation growth, the organic matter content of soils is predictably low and impairs soil structure. Therefore, it is advisable increasing the OM in soil through the addition of organic fertilizers and incorporation of plant residues such as leguminous plants into soils.



Map 9. Proposed optimal land use type in the winter of the study area.



Map 10. Proposed optimal land use type in the summer of the study area.

Table 6. The soil areas (feddan) and their proposed optimal land use type of the study area.

Crop type	Suitable class of soil	Crop alternatives	area	
			feddan	%
perennials	S2	Peach or Citrus or olive	32318	32.05
		Olive	21694	21.51
Winter annuals	S3	Wheat or potato or sugar beet	26845	26.62
	S4	Wheat or sugar beet or potato	14673	14.55
Summer	S3	Maize or soybean or sunflower	26845	26.62
annuals	S4	Maize or sunflower or melon	14673	14.55
	S5	Not suitable for any crop	5311	5.26

In connection with soil erosion, mechanical leveling should be averted to alleviate the possible unfortunate consequences of compaction and deterioration of soil structure that may aggravate soil erosion. Regarding alkaline soils, application of ammonium or potassium sulphates is recommended to decrease soil alkalinity. In connection with the soils classified as not suitable (S5), it is suggested that pasture and forestry would be the relevant land use. Since applying the management techniques are costly, it is advisable to follow intensive and conservative practices to keep up the high productivity.

In general, the Framework for Evaluating Sustainable Land Management (FESLM), proposed by Smyth *et al*. (1993), would be taken as instrumental reference and a strategic guide to identify the possible drawbacks and to increase the probability of advancement.

CONCLUSIONS

The study dealt mainly with soil classification and evaluation of the suitability for certain crops in areas located in the western desert fringe of El-Minia Governorate, covering an area about 100841 feddan, and to propose different crop alternatives and to recommend an appropriate sustainable management system. The study pointed out the following;

The study area includes three (3) landforms i.e. almost flat alluvial plain, gently undulating alluvial plain and undulating alluvial plain. They showed detectable amount of secondary formations of carbonates and gypsum throughout some layers with characteristics of diagnostic horizons. They are classified as *Typic Torripsamments, Typic Torriorthents, Lithic Torripsamments, Lithic Torriorthents, Typic Haplogypsids, Typic Calcigypsids, and Lithic Haplogypsids.* They were grouped into seven soil mapping units varied in depth, texture and topography.

With regard to the evaluation of soil resources potentialities; the most severe limitations are; coarse texture, moderately gravel content, and followed by the limited depth and poor internal drainage. Whereas the carbonate and sodium saturation are the least influential ones but not generally associated with specific soil mapping unit.

In general, the studied soils could be classified into four (4) suitability classes, i.e. suitable (S2) with 54012 feddan (53.5% of the total area) for olive, an area of 32318 feddan (32% of the total area) for citrus or peach; moderately suitable (S3) with 52657 feddan (52.2 % of the total area) for wheat or maize or melon or potato or soybean or sunflower or sugar beet, whereas there is an area of 36179 feddan (35.8 % of the total area) for either peach or citrus, meanwhile, olive can be grown in an area of 26845 fedda (26.6 % of the total area). As for the marginally suitable class (S4), and area of 42873 feddan (42.5 % of the total area) can be grown with either wheat or potato or sunflower or sugar beet; while maize or melon or soybean can be cultivated in an area of 42254 feddan (41.9 % of the total area) and an area of 20526 feddan (20.3 % of the total area) can be cultivated with peach and citrus and an area of 12756 feddan (12.6 % of the total area) can be cultivated with olive. The “not suitable” soils (S5) ranged from 5.2 to 11.7 % of the total study area.

It is recommended that a good land management system should be designed to overcome some of the temporarily limiting factors that may impede the optimum agricultural use.

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الملخص العربي

تقسيم التربة والإستخدام الزراعى الأمثل لبعض مناطق الظهير الصحراوى الغربى لمحافظة المنيا، مصر

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تعتبر الأراضى الواقعة فى غرب محافظة المنيا أحد المناطق الواعدة للتوسع الزراعى فى الصحراء الغربية المصرية ضمن المشروع القومى لاستصلاح مليون ونصف مليون فدان، لما بها من موارد تنموية تبشر بعائد إقتصادى مشجع ومؤات اذا ما أحسن استغلالها. تهدف الدراسة الحالية الى تقسيم وتقييم التربة لتحديد الإستخدام الزراعى الأمثل والمساهمة فى اقتراح نظام الإدارة المستدامة لبعض الأراضى الواقعة جنوب طريق بنى مزار – البويطى بالظهير الصحراوى الغربى لمحافظة المنيا، والتى تغطى مساحة قدرها ١٠٠٨٤١ فدان وبناءاً على الدراسة الحقلية والتحليلات المعملية والتحليل الطيفى للمرئية الفضائية للقمر الصناعى الأوربى Sentinel-2A مع التحليل الطبوغرافى للنموذج الرقمى للإرتفاعات DEM بإستخدام GIS، أمكن تمييز عدد (٣) وحدة أشكال أرضية مختلفة فى التنوع الطبوغرافي (الشبه مستوى – خفيف التموج – المتموج) للسهل الفيضى الذى يغطى منطقة الدراسة. وأجريت الدراسة بحصر أراضى المنطقة بإستخدام ١٨٥ قطاع أرضى ممثل للإختلافات الطيفية لسطح تربة الأشكال الأرضية السائدة بها ووصفت مورفوبيدولوجيا، وتم تجميع عينات التربة منها لإجراء التحليلات المعملية اللازمة لتقدير صفات وخصائص التربة الطبيعية والكيميائية، كما أمكن تقسيم تربة هذه الأشكال الأرضية السائدة لعدد (٧) وحدات خرائطية لمستوى تحت مجموعة عظمى طبقاً للتصنيف الأمريكى الحديث وهى:

Typic Torripsamments, Typic Torriorthents, Lithic Torripsamments, Lithic Torriorthents, Typic Haplogypsids, Typic Calcigypsids, and Lithic Haplogypsids.

كما قسمت الأراضى المدروسة حسب عمق التربة وقوامها وطبوغرافيتها الى ٧ وحدات خرائطية للتربة.

كذلك أمكن تقييم مدى صلاحية الأراضى لزراعة بعض المحاصيل المختارة بأستخدام نموذج ALMAGARA لبرنامج MicroLEIS. ووفقا لنتائج الدراسة إتضح أن أراضى الوحدة الخرائطية للتربة الثانية والرابعة هى أكثر صلاحية مقارنةً بكل من أراضى الوحدة الخرائطية للتربة الأولى والثالثة والخامسة والسادسة والسابعة حيث انهم صنفوا بدرجة هامشية الصلاحية (S4) لمعظم المحاصيل المختبرة وذلك لتأثرها ببعض العوامل الأرضية المحدة مثل القوام الخشن والعمق الضحل والاكثر ضحولة وسوء الصرف، وكذلك أوضحت الدراسة أن الأراضى التى تم دراستها يمكن زراعتها بالمحاصيل وفقا لذلك الترتيب وهو الزيتون، الخوخ، الموالح، القمح، البطاطس، عباد الشمس، بنجر السكر، الذرة، البطيخ، فول الصويا وذلك حسب الأولويات والاقتصاديات. كما إتضح من الدراسة أن حوالي من ٣٢.٣٪ إلى ٥٤٪ من المساحة الكلية للأراضى المدروسة تكون صالحة لزراعة أشجار الخوخ والموالح والزيتون، في حين أن ٥٢٪ من المساحة الكلية تكون صالحة بدرجة متوسطة للمحاصيل الحولية المختبرة، وتراوحت المساحات الغير مناسبة لزراعة المحاصيل المختبرة فى الدراسة من ٥.٣٪ إلى ١١.٨٪ من المساحة الكلية. كما تم إستخدم برنامج Arc-GIS لإنتاج الخرائط المعلوماتية المختلفة لوحدات الأشكال الأرضية وأنواع التربة ووحدات القدرة الإنتاجية والصلاحية لزراعة المحاصيل تحت الدراسة لإيضاح توزيعها المكانى. عموماً قدمت الدراسة دلائل كمية ومعلومات لنظام الأدارة الزراعية قد تكون من الأهمية بمكان لمتخذ القرار الزراعى فى إدارة الموارد الطبيعية وعملية التنمية الزراعية التشاركية بإقليم الظهير الصحراوى لمحافظة المنيا كنموذج لمناطق استصلاح وإستزراع المليون ونصف فدان.