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SOIL CAPABILITY AND SUITABILITY ASSESSMENT OF TUSHKA AREA, EGYPT BY USING DIFFERENT PROGRAMS (ASLE, MICROLEIS AND MODIFIED STORIE INDEX)

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ABSTRACT

The present study was undertaken to identify the morphological, physical and chemical characteristics of soils in Tushka, Aswan governorate, Egypt, in order to classify and evaluate them from the agricultural use view point. Tushka area is located in the western desert, upper Egypt. It lies between latitudes of 22° 48′ 00.7" and 22° 28′ 44.2'' N and longitudes of 31° 28′ 07.2" and 31° 29′ 08.2" E. The soils of the study area were none to slightly saline (ECe ranged from 0.53 to 6.85 dSm-1). Soil texture was mostly sand, loamy sand and sandy loam. Soil reaction (pH) tended to be mildly to moderately alkaline with a range of 7.6 to 8.1. Calcium carbonate and gypsum contents were very low. The soils were classified as Typic Torripsamments, Typic Torriorthents and Lithic Torriorthents. Most of the soils understudy were suitable for agricultural use. The results revealed that the capability of soils according to ASLE program was good (C2) and fair suitable (C3), moderate suitable (S3) using MicroLEIS (Cervatana model) and good, fair and poor using Modified Storie Index. Most of the selected crops were found to be the best grown ones on soils of the S2 and S3 suitability classes by ASLE program. Also, most of the selected crops were moderately (S3) and marginally suitable (S4) by MicroLEIS-ALMAGRA model. The main limitation factors of the study area for crop production were soil texture and soil depth.

KEYWORDS

Tushka, ASLE program, MicroLEIS, Modified Storie Index

1. INTRODUCTION

Egypt has an arid land with almost 96% of uninhabited parts of its territory. More than ninety million inhabitants are concentrated mainly in the Nile delta and valley as well as in the northern coastal zone along the Mediterranean Sea and in small areas of Western desert where lands are suitable for agricultural production [1,2].

The main challenge facing Egypt today is the need for better development and management of natural resources to meet the growing needs of the nation. The ratio between land and human resources is the most important problem in Egypt [3]. The horizontal agricultural expansion in the Western desert is one of the most important objectives of Egyptian agricultural policy to meet the food security needs of the growing population [4]. The agricultural expansion in new desert areas is also a priority to compensate the successive loss of agricultural land in Egypt [5].

Southwest Tushka area which lies south west of Egypt is considered as one of the promising areas for agricultural expansion and development [6]. Land assessment allows lands to be evaluated for agricultural use in accordance with their physical and chemical capacities as well as limitations to protect soil resources from degradation during potentialities achieving farmers' demands for optimal crop production [7]. Since wheat, barley, maize and sorghum are strategic crops in Egypt and most farmers devote high surface areas to grow wheat each year, these crops were selected to be evaluated for soil adequacy assessment of this area.

The general view of geology and geomorphology of the western desert, which includes the area understudy [8]. Essentially it is a desertic plateau with a vast flat expansion of rocky ground or numerous closed depressions. The greatest altitude is attained in the extreme south western corner where the general plateau character is disturbed by the great mountain of Gebel Uweinat. North of this mountain, a broad high terrain plateau, known as Gilf El-Kebir, extends for more than 200 km. This sandstone plateau is bordered in the south by a prominent escarpment, that descends gradually to the north and east directions forming a very extensive pediment sandy plain. This sandy plain is dotted in several parts by many rock exposures of Tertiary volcanic volcanic origin and basement complex rocks of granitites. Cretaceous rocks formed of what is called the Nubian formation, which is essentially sandstone, occupy the sand plain. In general, soil characteristics, classification and evaluation of some parts in Egypt using different programs (ASLE, MicroLEIS and Modified Storie Index) which were studied at regional stages were investigated by many researchers [9- 22]. The main objective of this research is to evaluate and compare the land suitability of Tushka area, Egypt for some principal crops using different evaluation systems. Several crops were selected to assess their convenience to be grown in the studied area. This study is needed to get useful information about these soils. It would help agricultural investment of various parts of Tushka area.

2. MATERIAL AND METHODS

2.1 Field Description and Soil Sampling

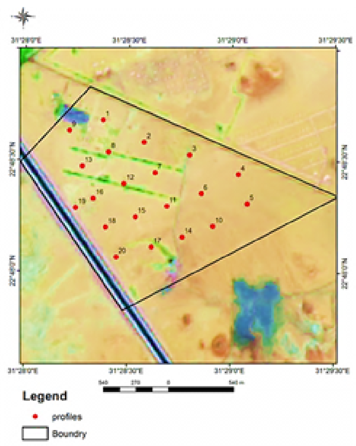


Figure 1: The soil profile location map of the study area

The area under investigation is located on the east side of Abu-Simbel/ Aswan road which is (km 50) north of Abu-Simbel city. It is a part of the western desert plateau and lies between latitudes 22°48′ 00.7" and 22°

48′ 00.7" and 22° 28′ 44.2'' N and longitudes 31° 28′ 07.2" and 31° 29′ 08.2" E (Figure 1). Twenty soil profiles were selected to represent the area under investigation according to the geological, topographic and recent aerial photographic maps of the study area. The profiles were dug down to parent rock and described for their morphological characteristics according to the standard procedures [23-25]. Soil samples were collected from profile layers according to the vertical morphological variations. The samples were air-dried, crushed, passed through a 2 mm sieve, and kept for different analysis. Soil color of both dry and moist samples was determined using Munsell color chart was determined [26]. The study also exploited the use of geographic information systems (GIS, ArcView, 10) for mapping the soils of the study area.

2.2 Climate of the Study Area

The most important climate characteristics necessary for the suitability determination (temperature, rainfall, relative humidity, etc.) were collected from Aswan metrological station. The study area has a mean annual rainfall of 1 mm/ year that is concentrated in the winter season, with mean relative humidity of 9.4% and a mean annual temperature of 26.3 °C (mean maximum temperature is 33.9 °C and the mean minimum temperature is 18.8 °C).

2.3 Laboratory Analysis

The gravels content was measured by volume according to a study [27]. Particle-size distribution of the studied soils was performed according to one study by a group researcher [28]. Soil reaction (pH) of 1:1 soil to water suspension was measured using a glass electrode [29]. Total Calcium carbonate (CaCO3) was determined by Collin's calcimeter [30, 31]. The electrical conductivity (ECe) of the solution soil paste extract was assessed by methods described in some studies [32]. Determination of soil gypsum content was done in using a graph showing the relation between the concentration and electrical conductivity of gypsum solution [30]. The exchangeable sodium percentage (ESP) of the soil samples was determined according to some research paper [32] using ammonium acetate method. The cation exchangeable capacity was measured by sodium oxalate method [33, 34].

2.4 Soil Classification

The dominant soil moisture regime is aridic (torric) with a hyperthermic soil temperature regime. The soils were classified up to the sub group according to Soil Taxonomy [25]. The results obtained from the visual interpretation and digital elevation model as well as field data were incorporated using GIS in order to produce the soil map of the study area.

2.5 Land Evaluation Methods

The studied soils were evaluated for land capability and suitability using several systems as follow:

a) Land capability classification

• Modified Storie Index Rating, [35]: The calculation was run and marked using Visual Basic for application under Microsoft Excel [36],
• MicroLEIS [37], Internet-based program, and
• Applied System of Land Evaluation (ASLE) program [38].

b) Land suitability classification.

• MicroLEIS [39], Internet-based program, and
• Applied System of Land Evaluation (ASLE) program [38].

3. RESULTS AND DISCUSSION

3.1 Main Morphological Aspects of the Studied Soils

The main morphological aspects of the studied soil profiles are shown in Table 1. The field description revealed that the topography of the landscape was almost flat to gently sloping. The elevation ranged between 192 and 208 m above sea level. Most of soil profiles were fairly well drained and the water table was deep (> 200 cm). Thus, the crop growth was not affected. The dominant soil color in the studied soil profiles was reddish yellow (5YR 7/6, dry) to yellowish red (5YR 4/6, moist) or reddish yellow (7.5YR 7/6, dry) to strong brown (7.5YR 5/6, moist). However, very pale brown (10YR 8/4, dry) to yellowish brown (10YR 5/6, moist) colors were also detected. This could possibly be attributed to the heterogeneity of parent materials and/or multi-depositional regime. No effervescence with dilute HCl was observed in all pedons indicating absence of CaCO3.The soil structure of most soil profiles was platy and subangular blocky; the consistence was slightly hard to extremely hard (dry) and loose to friable (moist). The area was virgin without any natural vegetation. The horizon boundaries were abrupt in distinctness and smooth to wavy in topography.

Table 1: The main morphological aspects of the studied soil profiles

Prof. No	Elevation A.S.L (m)	Horizon	Depth (cm)	Soil Color			Gravel	Texture (I)	Soil Structure (II)			Consistence (III)		Boundary (IV)
				Hue	Dry	Moist			Grade	Size	Type	Dry	Moist	
1	205	C1	0-20	10YR	8/4	5/4	few	LS	1	f	pl	sh	loose	as
		2C2	20-100	5YR	4/4	5/6	-	SL	2	c	pl	vh	friable	-
2	198	C1	0-25	10YR	8/4	5/6	-	LS	-	-	sl	so	loose	as
		2C2	25 - 50	10YR	8/4	7/4	-	S	2	m	pl	h	loose	aw
		2C3	50 - 100	5YR	6/6	5/6	-	S	2	m	pl	vh	friable	-
3	195	C1	0-15	7.5YR	7/4	5/6	-	S	1	f	pl	sh	loose	as
		2C2	15-70	7.5YR	6/4	5/6	-	LS	1	m	sbk	h	loose	-
4	193	C1	0-20	10YR	8/4	5/6	few	SL	-	-	sl	so	loose	as
		R	20-50	10YR	6/4	5/6	-	SL	2	m	pl	vh	friable	-
5	195	C1	0-15	7.5YR	6/5	4/4	-	SL	-	-	sl	so	Loose	aw
		2C2	15-30	10YR	8/4	5/6	-	LS	1	f	pl	sh	v. friable	-
		3C3	30 - 90	7.5YR	5/6	44/	-	SL	2	f	sbk	h	friable	
6	192	C1	0-20	5YR	7/6	4/6	few	SL	-	-	sl	so	loose	as
		C2	20-50	5YR	7/6	4/6	-	SL	1	f	sbk	h	v. friable	as
		C3	50 - 100	5YR	7/6	4/6	-	SL	2	f	pl	vh	friable	-
7	198	C1	0 - 15	7.5YR	5/6	4/4	-	SL	-	-	sl	so	Loose	as
		2C2	15 - 25	7.5YR	5/6	4/4	-	LS	1	f	pl	slh	v. friable	as
		2C3	25 - 40	7.5YR	5/6	4/4	-	LS	2	m	sbk	h	friable	aw
		2C4	40 - 90	10YR	8/4	6/6	-	LS	2	m	sbk	h	friable	-
8	205	C1	0-20	5YR	6/6	5/6	-	LS	1	f	pl	sh	loose	as
		C2	20-90	5YR	7/6	6/6	-	LS	2	m	sbk	h	friable	-
9	208	C1	0-20	10YR	7/4	5/6	-	LS	-	-	sl	so	Loose	as
		2C2	20 - 50	7.5YR	5/8	5/6	-	SL	2	m	sbk	h	friable	as
		2C3	50 - 80	7.5YR	7/6	5/8	-	SL	3	m	sbk	vh	friable	-
10	198	C1	0 - 25	7.5YR	7/6	5/6	-	SL	1	f	pl	slh	loose	as
		C2	25 - 60	7.5YR	7/6	5/6	-	SL	2	m	sbk	h	friable	-
11	195	C1	0-30	10YR	8/4	5/4	few	LS	-	-	sl	so	loose	as
		C2	30-100	7.5YR	7/6	5/6	-	LS	2	f	pl	h	friable	-
12	193	C1	0-30	7.5YR	7/4	5/6	few	SL	-	-	sl	so	loose	as
		2C2	30 - 70	10YR	8/4	7/4	-	LS	2	f	sbk	h	v. friable	aw
		3C3	70 - 100	5YR	7/6	5/6	-	SL	2	m	pl	vh	friable	-
13	198	C1	0 - 30	10YR	8/4	5/6	-	SL	-	-	sl	so	loose	as
		C2	30 - 80	10YR	8/4	7/4	-	SL	2	m	pl	h	friable	-
14	200	C1	0-30	10YR	4/8	4/4	-	SL	-	-	sl	so	loose	as
		2C2	30 - 60	7.5YR	6/4	4/4	-	LS	1	f	pl	h	friable	as
		2C3	60 - 80	7.5YR	6/4	4/4	-	LS	2	m	sbk	vh	friable	-
15	197	C1	0-15	7.5YR	7/4	5/6	-	LS	-	-	sl	so	loose	as
		C2	15-30	7.5YR	6/4	5/6	-	LS	1	f	pl	slh	v. friable	as
		2C3	30 - 70	7.5YR	6/6	5/6	-	SL	2	m	sbk	h	friable	-
16	196	C1	0-10	10YR	5/6	4/4	-	LS	-	-	sl	so	loose	as
		C2	10 - 50	10YR	5/6	4/4	-	LS	1	f	pl	slh	v. friable	aw
		2C3	50 - 100	10YR	5/3	4/3	-	S	2	co	pl	h	friable	-
17	195	C1	0-20	7.5YR	7/4	5/6	few	SL	-	-	sl	so	loose	as
		C2	20 - 40	10YR	6/2	5/3	-	SL	1	m	pl	h	friable	as
		C3	40 -70	10YR	8/4	5/6	-	SL	2	m	pl	exh	friable	-
18	194	C1	0-15	5YR	6/6	5/6	few	LS	1	f	pl	slh	loose	as
		C2	15 - 35	5YR	7/6	6/6	-	LS	2	m	bk	h	loose	as
		2C3	35 - 80	7.5YR	6/6	5/6	-	SL	2	m	pl	vh	v. friable	-
19	198	C1	0-30	7.5YR	7/6	5/6	-	LS	1	f	pl	slh	loose	as
		2C2	30-60	7.5YR	7/6	5/6	-	SL	2	m	sbk	h	v. friable	-
20	196	C1	0-20	7.5YR	7/6	5/6	few	LS	-	-	sl	so	loose	as
		2C2	20 - 50	7.5YR	6/6	5/6	-	SL	1	f	sbk	slh	v. friable	aw
		2C3	50 - 80	7.5YR	7/4	6/6	-	SL	2	f	pl	exh	friable	-

Abbreviations:
Texture (1): S = Sand, LS= Loamy Sand and SL= Sandy Loam
Soil structure (II): 1 = weak, 2= moderate, 3=strong, f=fine m=medium, co= coarse, sl=structureless, pl=platy and sbk= subangular blocky.
Consistence (III): so = soft, sh = slightly hard, h= hard, vh= very hard, and exh = extremely hard
Boundary (IV): as = abrupt smooth, and aw = abrupt wavy.

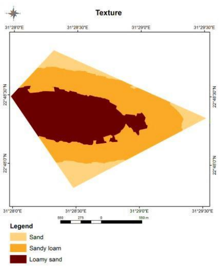
3.2 Main Physical and Chemical Properties of The Studied Soils

The main physical and chemical properties are given in Tables 2 and 3, respectively, and are illustrated in Figure 2. These results showed that the soil profiles were generally medium deep to deep and the soil texture was mainly coarse (sand, loamy sand and sandy loam). The calcium carbonate content ranged from 0.92 to 12.60 % with a general trend to decrease with depth. The results also displayed that the gypsum content was very low (< 0.5%). Soil reaction was mildly to moderately alkaline as indicated by pH values, which ranged between 7.6 and 8.1. In some cases, pH values of the surface layers were considerably higher than those of the subsurface ones. This pattern was conversely correlated with the concentration of total soluble salts. The soils of the study area were non-to slightly saline as the ECe values varied between 0.53 and 6.85 dSm-1, except in few soil samples that they were considered moderately saline as the ECe extended from 8.17 to 11.37 dSm-1.

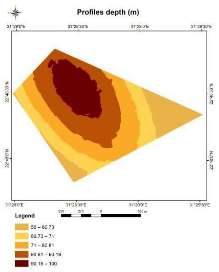
Table 2: Some physical properties of soils, as well as their taxa, of the studied profiles

Prof. No.	Depth of Layer (cm)	$CaCO_3$ %	Gypsum %	Soli Texture Grade	Classification
1	0 - 20	3.36	0.04	Loamy Sand	Typic Torriorthents
	20 - 100	2.94	0.06	Sandy Loam	
2	0 - 25	6.32	0.05	Loamy Sand	Typic Torripsamments
	25 - 50	2.10	0.05	Sand	
	50 - 100	1.76	0.05	Sand	
3	0 - 15	10.5	0.10	Sand	Typic Torripsamments
	15 – 70	1.51	0.08	Loamy Sand	
4	0 - 20	7.14	0.06	Sandy Loam	Lithic Torriorthents
	20 - 50	2.18	0.07	Sandy Loam	
5	0 - 15	2.02	0.36	Sandy Loam	Typic Torriorthents
	15 - 30	2.18	0.13	Loamy Sand	
	30 - 90	2.10	0.18	Sandy Loam	
6	0 - 20	10.92	0.06	Sandy Loam	Typic Torriorthents
	20 - 50	3.44	0.07	Sandy Loam	
	50 - 100	5.54	0.02	Sandy Loam	

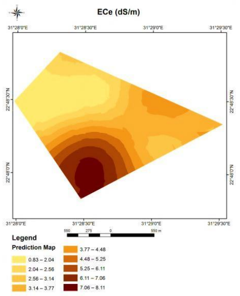
7	0 - 15	1.85	0.07	Sandy Loam	Typic Torripsamments
	15 - 25	2.02	0.05	Loamy Sand	
	25 – 40	1.01	0.06	Loamy Sand	
	40 - 90	9.32	0.05	Loamy Sand	
8	0 - 20	5.04	0.06	Loamy Sand	Typic Torripsamments
	20 - 90	1.68	0.15	Loamy Sand	
9	0 - 20	3.11	0.07	Loamy Sand	Typic Torriorthents
	20 - 50	2.52	0.11	Sandy Loam	
	50 - 80	9.41	0.06	Sandy Loam	
10	0 - 25	2.10	0.05	Sandy Loam	Typic Torriorthents
	25 - 60	2.94	0.04	Sandy Loam	
11	0 - 30	3.28	0.02	Loamy Sand	Typic Torripsamments
	30 - 100	1.93	0.03	Loamy Sand	
12	0 - 30	3.86	0.06	Sandy Loam	Typic Torripsamments
	30 - 70	1.76	0.07	Loamy Sand	
	70 - 100	0.92	0.07	Sandy Loam	
13	0 - 30	11.0	0.12	Sandy Loam	Typic Torriorthents
	30 - 80	9.66	0.03	Sandy Loam	
14	0 - 30	3.78	0.06	Sandy Loam	Typic Torripsamments
	30 - 60	1.26	0.04	Loamy Sand	
	60 - 80	1.60	0.01	Loamy Sand	
15	0 - 15	7.14	0.04	Loamy Sand	Typic Torripsamments
	15 - 30	4.37	0.05	Loamy Sand	
	30 - 70	4.79	0.04	Sandy Loam	
16	0 - 10	3.53	0.06	Loamy Sand	Typic Torripsamments
	10 - 50	1.26	0.06	Loamy Sand	
	50 - 100	1.09	0.03	Sand	
17	0 - 20	9.66	0.09	Sandy Loam	Typic Torriorthents
	20 - 40	3.36	0.19	Sandy Loam	
	40 - 70	1.26	0.08	Sandy Loam	
18	0 - 15	9.24	0.10	Loamy Sand	Typic Torriorthents
	15 - 35	5.46	.040	Loamy Sand	
	35 - 80	10.16	0.09	Sandy Loam	
19	0 - 30	5.12	0.03	Loamy Sand	Typic Torripsamments
	30 - 60	3.44	0.18	Sandy Loam	
20	0 - 20	4.20	0.09	Sandy Loam	Typic Torriorthents
	20 - 50	5.46	0.05	Sandy Loam	
	50 - 80	12.60	0.06	Sandy Loam	



Soil texture map



Soil depth map



Soil salinity (ECe) map

The low values of electrical conductivity (ECe) may be due to free drainage conditions. Most of soil profiles showed a clear increase in the soluble salts with depth. Moreover, these soils exhibited no sodicity as they had exchangeable sodium percentage (ESP) values that were less than 15 % and sodium adsorption ratio (SAR) values which were less than 13, except the subsurface layer of profile 18 that showed a SAR value that was higher than 13 (18.11). The examined soil samples displayed that the cation exchange capacity (CEC) was very low (5.11 – 14.65 cmol (+)/kg) due to their coarse texture and their extremely low content of organic matter due to the prevailing arid climate and barren nature of the soils [6]. The predominant climate of the study area was extremely arid, and the dominant soil moisture regime was aridic (torric) with a hyperthermic soil temperature regime. The investigated soils are classified according to Soil Survey Staff (2014) as Typic Torripsamments, Typic Torriorthents and Lithic Torriorthents (Table 2 and Figure 3).

Table 3: Some chemical properties of studied soil profiles

Prof. No.	Depth of Layer (cm)	PH (1:1)	EC_e (dSm^{-1})	ESP %	SAR	CEC cmol (+)/kg
1	0 - 20	7.9	3.70	2.98	4.56	9.22
	20 - 100	8.0	3.33	3.97	3.93	8.51
2	0 - 25	7.7	1.58	2.01	3.33	9.21
	25 - 50	7.6	0.66	0.86	1.20	7.11
	50 - 100	7.9	0.53	0.54	1.38	7.35
3	0 - 15	7.7	1.42	2.47	3.99	6.42
	15 – 70	7.7	3.50	11.99	9.99	5.21
4	0 - 20	7.9	2.94	5.09	4.38	13.12
	20 - 50	7.7	6.12	4.17	5.21	10.24
5	0 - 15	7.67	3.73	7.43	8.09	6.61
	15 - 30	7.6	5.10	5.60	8.71	8.93
	30 - 90	8.1	2.13	4.11	4.61	9.32
6	0 - 20	7.8	1.46	3.72	3.0	12.51
	20 - 50	7.6	4.74	6.76	11.26	13.22
	50 - 100	7.6	3.95	2.72	2.32	14.65
7	0 - 15	8.0	5.01	6.67	5.78	10.52
	15 - 25	7.9	1.72	6.38	4.13	7.34
	25 – 40	7.8	2.85	3.66	9.14	6.44
	40 - 90	7.8	1.50	1.38	2.52	5.82
8	0 - 20	.81	2.22	1.56	3.24	8.21
	20 - 90	7.7	1.12	3.70	2.87	7.95
9	0 - 20	8.0	0.90	1.81	2.20	6.44
	20 - 50	8.1	0.75	6.26	2.31	13.47
	50 - 80	8.0	1.32	4.16	4.82	12.67
10	0 - 25	8.0	2.09	2.33	3.34	12.78
	25 - 60	7.9	2.24	5.21	5.90	10.36
11	0 - 30	7.9	2.49	3.50	5.05	7.41
	30 - 100	.78	4.80	4.97	9.10	8.53
12	0 - 30	7.9	1.81	1.66	4.45	9.64
	30 - 70	8.0	0.70	1.33	3.05	5.23
	70 - 100	7.8	0.77	1.64	1.80	10.42
13	0 - 30	7.7	1.78	1.98	3.37	5.38
	30 - 80	7.8	1.52	6.23	6.00	7.22
14	0 - 30	7.9	3.57	3.21	7.66	7.64
	30 - 60	7.9	6.77	4.96	10.45	5.11
	60 - 80	7.9	5.94	2.72	6.86	8.46
15	0 - 15	7.7	1.96	2.53	3.05	8.59
	15 - 30	7.8	1.26	1.39	2.46	6.37
	30 - 70	.78	9.50	6.25	2.69	10.65
16	0 - 10	7.8	3.34	1.99	3.78	8.11
	10 - 50	7.8	5.78	2.51	8.86	6.41
	50 - 100	8.0	3.37	2.20	5.61	5.24
17	0 - 20	7.9	2.57	3.09	4.22	9.12
	20 - 40	7.9	6.85	5.07	9.46	9.34
	40 - 70	8.0	11.00	6.51	2.29	7.58
18	0 - 15	8.1	1.40	1.93	3.17	6.22
	15 - 35	7.9	2.55	3.90	7.15	8.41
	35 - 80	.79	6.75	10.48	18.11	8.67
19	0 - 30	.77	2.41	1.73	5.11	5.33
	30 - 60	7.7	0.69	4.97	2.86	12.55
20	0 - 20	7.9	3.12	2.32	4.47	8.23
	20 - 50	7.9	8.17	7.03	11.05	7.95
	50 - 80	7.8	11.37	4.17	7.21	10.69

Where:
ESP = Exchangeable Sodium Percent
SAR = Sodium Adsorption Ratio

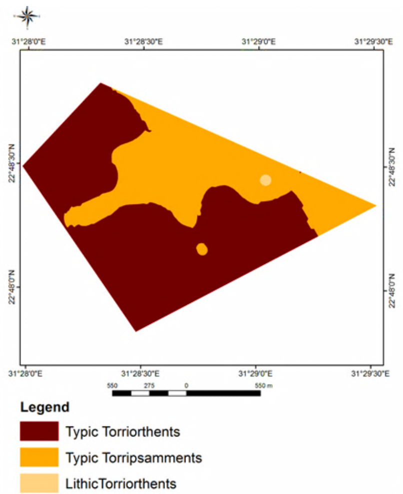


Figure 3: Soil classification map (subgroup level) of the study area

3.3 Land Evaluation

3.3.1 Land Capability Classification

Most of the land characteristics that were considered in the evaluation of the current land units under irrigation, ranged from very favorable to favorable for agricultural purposes. Qualitative land suitability studies were conducted using Modified Storie Index, MicroLEIS (Cervatana model) and Applied System of Land Evaluation (ASLE) program. Other information concerning climatic conditions and agricultural products were also used to predict the general land capability. From the agriculture point of view, soils of the study area are considered as promising soils. Evaluating their capability is an essential stage for the future practical use. Quantitative estimation of soil characteristics such as slope, drainage conditions (wetness), soil depth, texture, calcium carbonate content, gypsum status, salinity and sodicity were used in the land evaluation. The rating capability values and kinds of limitation condition types of the studied soils are present in Tables 4, 5 and 6 and illustrated in Figures 4. It is clear that none of the soil profiles was observed to be highly suitable (S1). It may be attributed to the slight or moderate limitations that are present in the study area. Accordingly, the study area could be classified into three classes as follow:

Class 2: This class includes the soils which are moderately suitable with a capability index (Ci) that varies between 60.85 and 63.68 % (ASLE program) and good (Modified Storie Index). However, it disappears using MicroLEIS- CERVATANA model. It occupies 20 and 5 % of the total area using ASLE program and Modified Storie Index, respectively. The soils of this class have slight limitations.

Class 3: This class contains the soils which have marginally suitable capability class C3 and capability index (Ci) that varies between 45.07 and 59.05% (ASLE program), fair (Modified Storie Index) and moderate (MicroLEIS- CERVATANA model). It occupies 80, 50 and 100 % of the study area using these respective land capability systems. The soils of this class are affected by moderate limitations.

Class 4: According to ASLE program this class comprises the soils which are not suitable for agricultural use, but they are suitable for pasture, have severe limitations that can be corrected and cover 45% of the study area. None of these land units was observed to be not suitable using Modified Storie Index and MicroLEIS- CERVATANA model [2, 22].

It could be concluded that the applied system of land evaluation (ASLE) is the most suitable program. It is preferable to be used as a qualitative land capability system for agricultural purposes. Compared to the other two programs, it is compatible with the Egyptian conditions. ASLE program can be also used by decision makers when they plan for future land utilization. The results of the current study indicated that the most limiting factors were soil texture followed by soil depth. Under good conditions of water availability for agricultural purposes, the moderately and marginally suitable soils (S2 and S3) could be safely used for agriculture.

Table 4: Land capability classes, grades and rating using ASLE program, MicroLEIS (Cervatana model) and Modified Storie Index

ASLE Program			MicroLEIS (Cervatana model)		Modified Storie Index		
Class	Grade	Rating (%)	Class	Grade	Class	Grade	Rating (%)
C1	Excellent	80- 100	S1	Excellent	Grade1	Excellent	80- 100
C2	Good	60 - 79	S2	Good	Grade 2	Good	60 - 79
C3	Fair	40 - 59	S3	Moderate	Grade 3	Fair	40 - 59
C4	Poor	20 - 39	N	Marginal or Nil	Grade 4	Poor	20 - 39
C5	Very Poor	10 - 19	--	--	Grade 5	Non agricultural	< 20
C6	Non agricultural	< 10	--	--	--	--	--

Table 5: Land capability classification of the studied soil profiles using ASLE, MicroLEIS and Modified Storie Index

Profile No.	ASLE Program			MicroLEIS (Cervatana model)	Modified Storie Index
	Class	%	Grade	Class	Class
1	C3	55.38	Fair	S3r	Grade 3
2	C3	57.22	Fair	S3r	Grade 3
3	C3	45.07	Fair	S3r	Grade 4
4	C3	52.84	Fair	S3r	Grade 4
5	C3	59.05	Fair	S3r	Grade 3
6	C2	63.68	Good	S3r	Grade 3
7	C3	57.01	Fair	S3r	Grade 3
8	C3	58.71	Fair	S3r	Grade 3
9	C2	60.85	Good	S3r	Grade 3
10	C2	61.55	Good	S3r	Grade 4
11	C3	54.25	Fair	S3r	Grade 3
12	C2	61.89	Good	S3r	Grade 2
13	C3	52.65	Fair	S3r	Grade 3
14	C3	52.71	Fair	S3r	Grade 4
15	C3	49.23	Fair	S3r	Grade 4
16	C3	55.2	Fair	S3r	Grade 4
17	C3	51.22	Fair	S3r	Grade 4
18	C3	55.01	Fair	S3r	Grade 4
19	C3	50.27	Fair	S3r	Grade 3
20	C3	50.14	Fair	S3lr	Grade 4

l: Soil limitations (mainly salinity)
r: Erosion risk (mainly no vegetation cover)

Table 6: Land capability classification of the study area according to ASLE Program, MicroLEIS (Cervatana model) and Modified Storie Indexf the studied soil profiles using ASLE, MicroLEIS and Modified Storie Index

Class	Area (%)	Class	Area (%)	Class	Area (%)
C2	20	--	--	S2	5
C3	80	S3	100	S3	50
C4	--	--	--	S4	45

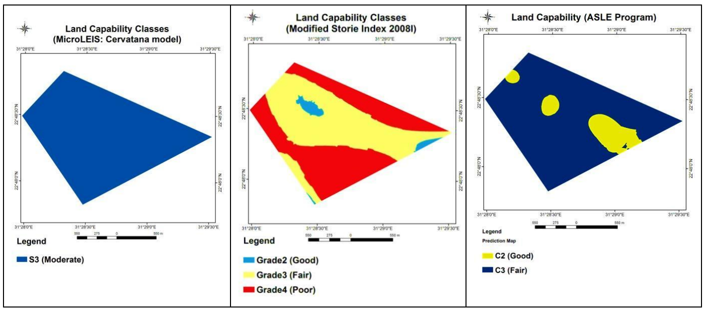


Figure 4: Land capability maps of the study area using different evaluation programs

The results of this research showed that 90% of total area was suitable for agricultural use. The area currently lacks soils of high capability for agricultural use. However, improving the soil properties and applying modern irrigation systems, the soil could be improved to be highly suitable for agricultural use. One of the best ways to improve such light soils (sandy soils) is through additions of organic materials. Good sources of organic matter include manures, leaf mold, sawdust, and straw. Many farmers enrich soils with natural fertilizers, such as animal manure, green manure, and compost. Continuous agriculture use of these soils will upgrade their suitability in the future.

3.3.2 Soil Suitability Classification

Land suitability assessment for agriculture is means to evaluate the ability of a piece of land to provide the optimal ecological requirements for a certain crop variety. In other words, it evaluates the capability of land in enabling optimum crop development and maximum productivity. This evaluation needs a specification of the respective crop requirements and calibrating them with the nature of the land and soil parameters. The current study used two programs, namely applied system of land evaluation (ASLE) and MicroLEIS (ALMAGRA model) which were used in the study area for the land use types of different field crops. The studied soil profiles were evaluated to determine their suitability for growing different crops according to these two programs. The soil parameters used for estimating the suitability index for different crops were, climate, slope, drainage, texture, soil profile depth, calcium carbonate, gypsum status, pH, salinity and sodicity.

The results indicate that the area under consideration has a good potential to produce field crops under irrigation, provided that the water requirements are met. Eleven crops were elected to assess their suitability for agriculture, namely alfalfa, wheat, maize, cotton, soybean, sunflower, sugar beet, watermelon, potato, citrus and olive. These crops are most suitable for arid and semi-arid soils (Tables 7, 8 and 9) and are illustrated in Figures 5, 6 and 7.

Table 7: Land suitability classes of the study area for different crops using the ASLE program

Profile No.	Soil Suitability (ASLE Program)										
	Wheat	Maize	Watermelon	Potato	Soya bean	Cotton	Sunflower	Sugar beet	Alfalfa	Citrus	Olive
1	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2	S2
2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
3	S2	S3	S2	S2	S3	S3	S2	S2	S2	NS1	S4
4	S2	S2	S2	S2	NS1	S4	S4	S2	S2	S4	S4
5	S2	S2	S2	S2	S3	S2	S2	S2	S2	S3	S2
6	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S1
7	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2	S2
8	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2	S2
9	S2	S2	S2	S2	S3	S2	S2	S2	S2	S4	S4
10	S2	S2	S2	S2	S3	S2	S2	S2	S2	S4	S4
11	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2	S2
12	S2	S2	S1	S2	S2	S2	S2	S2	S2	S2	S2
13	S2	S2	S2	S2	S3	S3	S2	S2	S2	NS1	S4
14	S2	S3	S2	S2	S3	S2	S2	S2	S2	NS1	S4
15	S2	S2	S2	S2	S3	S2	S2	S2	S2	S4	S4
16	S2	S2	S2	S2	S3	S2	S2	S2	S2	S2	S2
17	S2	S2	S2	S2	S3	S2	S2	S2	S2	NS1	S4
18	S2	S2	S2	S2	S3	S2	S2	S2	S2	S4	S4

19	S2	S2	S2	S2	S3	S3	S2	S2	S2	NS1	S4
20	S2	S2	S2	S2	S3	S2	S2	S2	S2	NS1	S4

S1 = highly suitable S2 = suitable S3 = moderately suitable
S4 = marginally suitable NS1 = currently not suitable NS2 permanent not suitable

Table 8: Land suitability classes of the study area for different crops using MicroLEIS-Almagra model

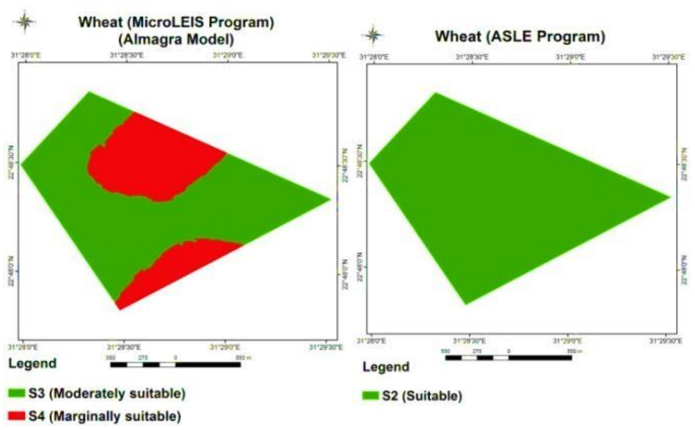
Profile No.	Soil Suitability (MicroLEIS-ALMAGRA Model)										
	Wheat	Maize	Water melon	Potato	Soya bean	Cotton	Sunflower	Sugar beet	Alfalfa	Citrus	Olive
1	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
2	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
3	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
4	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
5	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
6	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
7	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
8	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
9	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
10	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
11	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
12	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
13	S3	S3	S3	S3	S3	S3	S3	S3	S3	S2	S2
14	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3
15	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
16	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S2
17	S3	S3	S3	S3	S3	S3	S3	S3	S3	S4	S3
18	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
19	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
20	S3	S3	S3	S3	S3	S3	S3	S3	S3	S4	S3

S1 = highly suitable S2 = suitable S3 = moderately suitable
S4 = marginally suitable NS1 = currently not suitable NS2 permanent not suitable

Table 9: Soil suitability rating and percentage for growing some crops according to ASLE program and MicroLEIS-Almagra model.

ASLE program											
Rating suitability	Watermelon	Alfalfa	Wheat	Sugar beet	Potato	Maize	Sunflower	Cotton	Olives	Soya bean	Citrus
S1	5	--	--	--	--	--	--	--	5	--	--
S2	95	100	100	100	100	90	95	80	40	15	40
S3	--	--	--	--	--	10	--	15	--	80	5
S4	--	--	--	--	--	--	5	5	55	--	25
NS1	--	--	--	--	--	--	--	--	--	5	30
NS2	--	--	--	--	--	--	--	--	--	--	--
MicroLEIS-Almagra model											
Rating suitability	Olives	Watermelon	Alfalfa	Wheat	Sugar beet	Potato	Maize	Sunflower	Cotton	Soya bean	Citrus
S1	--	--	--	--	--	--	--	--	--	--	--
S2	60	--	--	--	--	--	--	--	--	--	30
S3	40	65	65	65	65	65	65	65	65	65	60
S4	--	35	35	35	35	35	35	35	35	35	10
NS1	--	--	--	--	--	--	--	--	--	--	--
NS2	--	--	--	--	--	--	--	--	--	--	--

S1 = highly suitable S2 = suitable S3 = moderately suitable
S4 = marginally suitable NS1 = currently not suitable NS2 = permanent not suitable



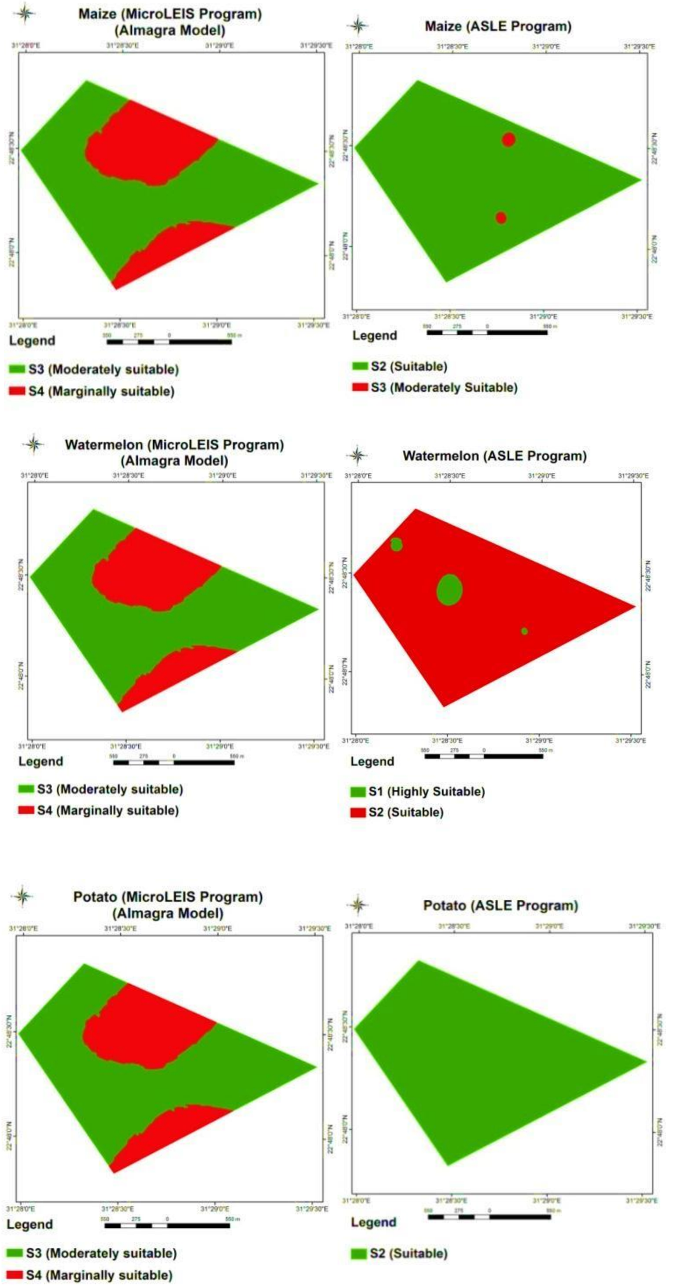
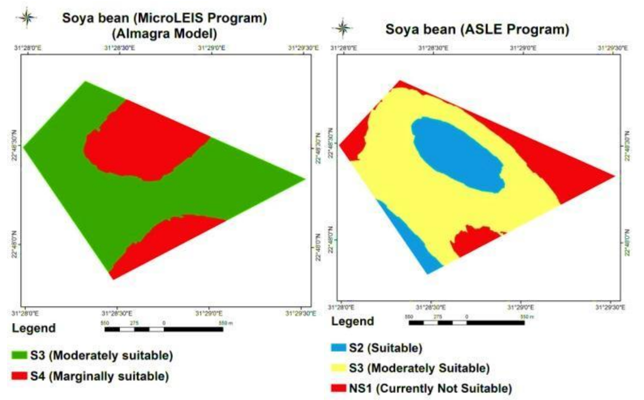


Figure 5: Land suitability maps for wheat, maize, watermelon and potato using ASLE and MicroLEIS (Almagr Model) programs



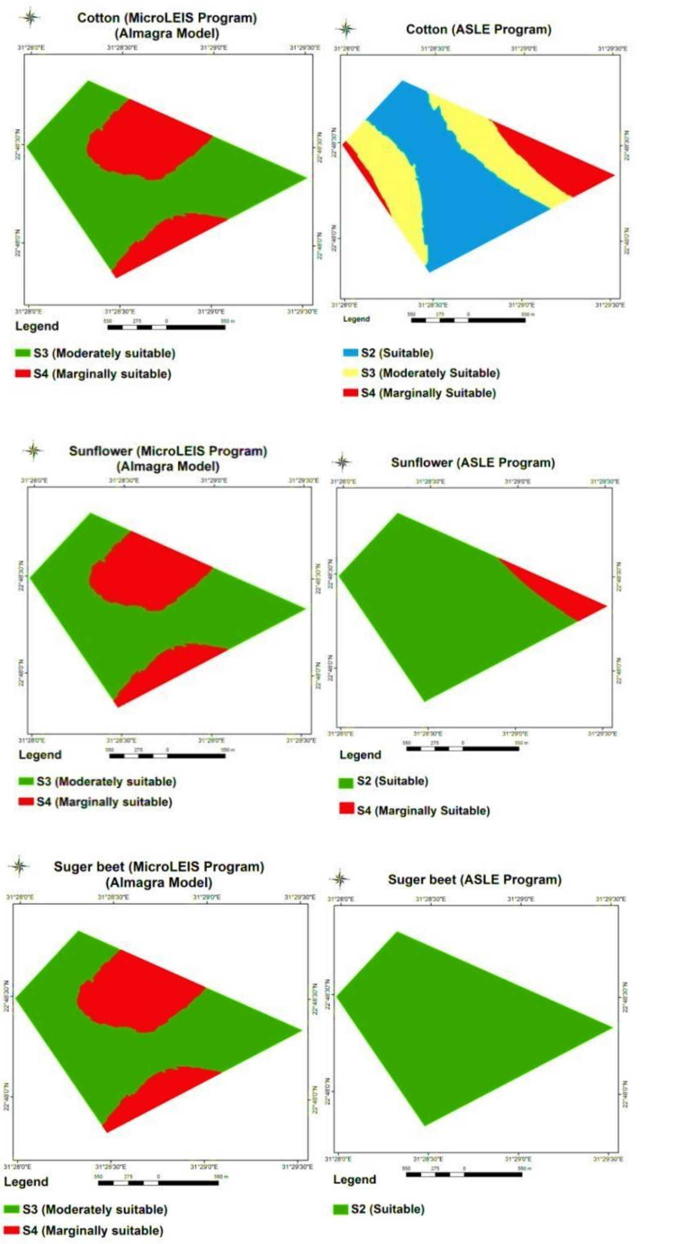
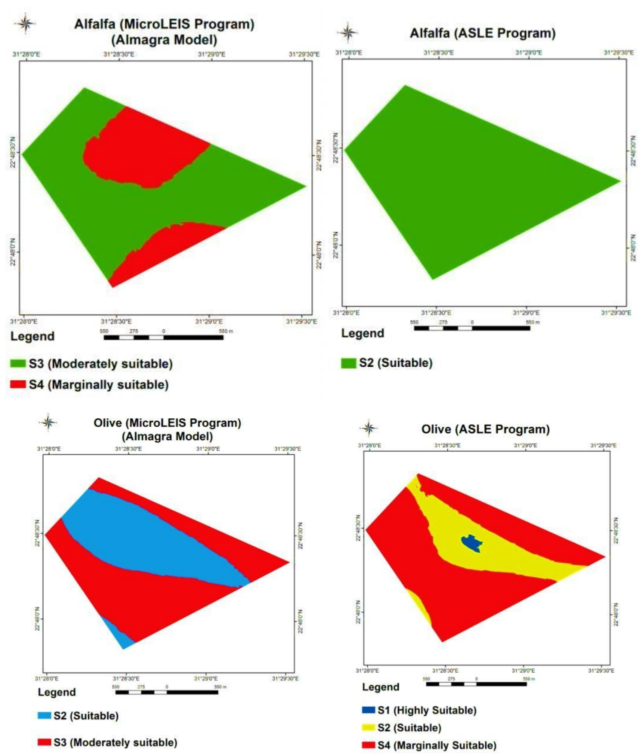


Figure 6: Land suitability maps for soybean, cotton, sunflower and sugar beet using ASLE and MicroLEIS (Almagr Model) programs



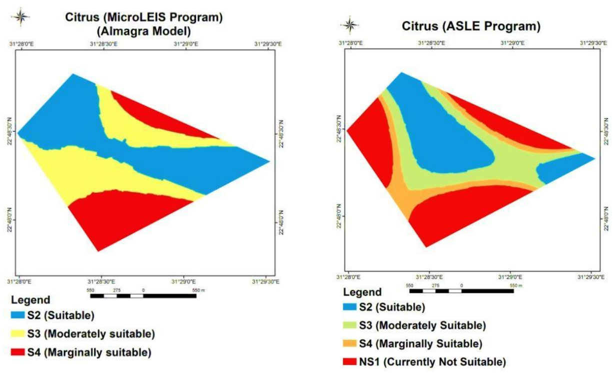


Figure 7: Land suitability maps for alfalfa, olive and citrus using ASLE and MicroLEIS (Almagr Model) programs

3.3.3 Applied System of Land Evaluation (ASLE program)

According to the applied system of land evaluation (ASLE program), the results indicated that 5% of the total study area are highly suitable (S1) and 95% are suitable (S2) for watermelon. All the study area (100 %) is suitable (S2) for alfalfa, wheat, sugar beet and potato. About 90% of the agricultural area are suitable and 10% are moderately suitable (S2) for maize. Most of the area (95%) is suitable (S2) and 5% are marginally suitable (S4) for sunflower. For cotton cropping, 80% of the area are suitable, while 15% and 5% are moderately and marginally suitable, respectively. A small area (5%) is highly suitable (S1), 40% are suitable and 55% are marginally suitable (S4) for growing olive. About 15 and 40% are suitable (S2), 80 and 5% are moderately suitable (S3), and 5 and 30% of the study area are not currently suitable (NS1) for soybean and citrus, respectively. Moreover, 25% of the total study area are marginally suitable (S4) for citrus cropping.

3.3.4 MicroLEIS, ALMAGRA Model

The current land suitability for different crops produced by MicroLEIS, ALMAGRA model showed that about 60 % of the studied area are suitable (S2) and 40% are moderately suitable (S3) for olive. Crops such as: watermelon, alfalfa, wheat, sugar beet, potato maize, sunflower, cotton and soybean are moderately suitable (65%) and marginally suitable (35%) to be grown in this area (Tables 8 and 9 and Figures 5, 6 and 7). For growing citrus, about 30% of area are suitable, while 60% and 10% are moderately and marginally suitable, respectively [5, 14, 20, 22].

Some crops are considered unsuitable (NS1) due to the moderate to severe fertility limitations of the study area, soil depth and coarse texture. The coarse texture, shallow depth, and salinity of the soils in some soil profiles are the main limiting factors for growing crops especially fruit trees. Proper fertilization and management associated with intensive leaching can improve the soil suitability for growing various crops under consideration. Many options such as, use of crops which are categorized as suitable to the area can be raised for the sustainable use of the land for producing different crops. Correcting some limiting factors, such as pH through the application of organic fertilizers which can reduce the alkalinity of the soil and increase the soil organic matter through crop residue management are also options to increase the suitability of these soils for crop production.

4. CONCLUSIONS

The purpose of this study was to evaluate the soil capability and suitability of Tushka area for crop production and identify the factors that hinder the cultivation process. Agricultural land identification, according to its own ecological potentialities and limitations is a major objective of land use planning. This study implies a qualitative evaluation for the actual soil parameters to realize a precise and objective interpretation for the area under consideration and its suitability for a wide range of crops. The most effective soil parameters that influenced the land suitability of the study area were texture, soil depth and salinity. From applying different systems used for capability assessment (ASLE program, MicroLEIS and Modified Storie Index), most of the studied soils are good and moderately suitable for agriculture. The ASLE program was found to be suitable for the land suitability assessment for agricultural proposes of the study area. It is convenient to be used under Egyptian conditions. Also, it is more realistic for the application in arid and semi-arid areas. From the agriculture point of view, soils of the study area are considered as promising ones. Applying some corrections on the limiting soil factors, the potential capability of the soils will be improved. Some selected crops such as watermelon, alfalfa, wheat, sugar beet, potato maize, olive and sunflower are recommended to be grown in the study area. On the other hand, the soil maps produced for agricultural land suitability in this research can be helpful in carrying out the management processes.

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