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Land suitability of some soils at Wadi Samhuod, Qena governorate, Egypt

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Abstract

Twenty-nine soil profiles (109 soil samples) representing the different geomorphological units of wadi Samhuod, that located North-West of Qena governorate, Egypt were selected to evaluate their suitability for growing various crops. The soils had coarse texture grades of sand, loamy sand, and sandy loam. The soil salinity varied from nonsaline to highly saline (EC_e 1.1 - 375.0 dS/m) with low values of organic matter (0.03 to 0.79%) and low available amounts of N, P and K. Some of the studied soils are considered as calcareous. The gypsum content in most samples is low, whereas some samples are considered as sodic soils. Two modern programs including the applied system of land evaluation (ASLE) for arid and semi-arid areas and microcomputer land evaluation information system (MicroLEIS) were applied to assess the suitability to grow some crops in these regions. Appling ASLE program verified that the soils of the study area were highly suitable, suitable, moderately suitable, marginally suitable, currently not suitable, and permanently not suitable for 9 field, vegetable crops, fruits and frog crops. The land suitability using MicroLEIS (Almagra model) program indicated that the soils of this area were moderately suitable, marginally suitable, and non-suitable for some crops due to one or more of the limiting factors. The main soil limitations of these soils were coarse soil texture, soil salinity, calcium carbonate and low soil fertility. However, the soil limitations are not permanent and can be improved through following proper management practices.

Keywords: Wadi Samhuod, land suitability, ASLE program, microLEIS, Almagra model.

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1. Introduction

Land suitability analysis is a prerequisite for sustainable agricultural production. It involves evaluation of criteria ranging from terrain to socio-economic, market and infrastructure. Many of these factors are vaguely defined and characterized by their inherent vagueness. Multi-criteria decision-making techniques like ranking, rating etc. are employed for suitability analysis. As this process incorporates expert knowledge and judgment by decision makers at various levels, it is very subjective in nature. Although techniques like Analytic Hierarchy Process (AHP) incorporate experts' knowledge but fails to address the inherent uncertainty in many factors like soil pH, fertility, etc., which vary continuously over the space, and it is not possible to modeled as it (Prakash, 2003). The process of mapping soil involves identifying the spatial distribution of its physical, chemical, and biological qualities and presenting them clearly to different users. Project design, fieldwork preparation, picture interpretation and auxiliary data preprocessing, field data collection and laboratory analysis, data entry and organization, and presentation and dissemination of soil survey results are the aspect of the main phase (Dent and Young, 1981). For diagnostic criterion there will be critical values or sets of critical values, which are used to define suitability class limits. The results obtained with the Applied System of Land Evaluation (ASLE) software when evaluating some soils of Wadi Tag El-Wabar show that the very suitable class (S1) is recorded for grapes, fig and date palm. Moreover, the suitable class (S2) is registered for wheat, barley, faba bean, sugar beet, sunflower, maize, soya bean, peanut, cotton, sugarcane, alfalfa, sorghum, pea, potato, citric, grape, apple, pear, fig and date palm. However, the moderately suitable class (S3) is found for wheat, barley, faba bean, sugar beet, soya bean, cotton, sugarcane, alfalfa, sorghum, apple, pear and fig. The results also indicate that the marginally suitable class (S4) is recorded for wheat, faba bean, sugar beet, sunflower, peanut, cotton, sugarcane, alfalfa, pea, potato, tomato, citric, grape, fig and date palm. On the other hand, the currently not suitable class (NS1) is listed for wheat, barley, faba bean, sugar beet, sunflower, rice, maize, soya bean, peanut, cotton, onion, sugarcane, alfalfa, sorghum, cabbage, pea, potato, pepper, watermelon, citric, banana, olive, grape, apple, pear, fig and date palm. Meanwhile, the permanently not suitable class (NS2) is recorded for faba bean, rice, soya bean, peanut, cotton, onion, sugarcane, cabbage, pea, potato, tomato, pepper, watermelon, citric, banana, olive, grape, apple, pear and fig (El-Sayed, 2021). Abd El-Aziz (2018) studied the soil suitability assessment of Tushka area, Egypt using different programs (ASLE, micro-LEIS and Modified Storie Index). According to the applied system of land evaluation (ASLE program), he found 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 is suitable and 10% are moderately suitable (S2) for maize. Most of the area (95%) is suitable (S2) and 5% are marginally suitable (S4) for sunflowers. For cotton cropping, 80% of the area is 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 olives. 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 is marginally suitable (S4) for citrus cropping. The current land suitability for different crops produced by MicroLEIS (Almagra model) showed that about 60 % of the studied area is 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. For growing citrus, about 30% of area is suitable, while 60% and 10% are moderately and marginally suitable. Rashed and Mark (2020) examined the classification and mapping of land productivity and suitability for crop production in West El-Minia governorate. The used land suitability for different crops produced by Micro LEIS-Almagra model showed that about 20% of the studied area are suitable (S2), 40% are moderately suitable (S3), 20% are marginally suitable (S4) and 20% are not suitable (S5) for wheat, sugar beet, soybean, sunflower and alfalfa. Crops such as maize, potato, cotton and watermelon are moderately suitable (60%), marginally suitable (20%) and not suitable (20%) to be grown in this area. For growing peach and citrus, about 80% of the area is moderately suitable (S3) and 20% are marginally suitable (S4). About 60% of the studied areas are suitable (S2), 20% are moderately suitable (S3) and 20% are not suitable for olive. The crops which are considered not suitable (S5) might be due to the moderate to severe fertility limitations of the study area. The coarse texture and shallow soil depth in some soil profiles are the main limiting factors for growing crops, especially fruit trees. Proper fertilization and management associated can improve the soil suitability for growing different crops. Applied ASLE programs proved that the soils of North-West of Dashlut, Assiut were highly suitable, suitable, moderately suitable, marginally suitable, and currently not suitable and permanently not suitable for 28 field and vegetable crops and fruits. The land suitability using Micro LEIS (Almagra model) program indicated that the soils of this area were moderately suitable, marginally suitable, and non-suitable for the selected crops due to one or more of the limiting factors (Sayed and Khalafalla 2021). The aim of this study is to evaluate land suitability for growing some selected crops using ASLE and micro-LIES (Almagra model) programs under drip and sprinkler irrigation systems.

2. Materials and methods

2.1 Location and climate

Qena governorate located 579 km south of Cairo, Egypt. Wadi Samhoud is found within the north-western portion of Qena governorate in the western desert (Figure 1). It expands from the west of Abu Tesht district to the northwest of the Nag Hammadi district (31° 52′ 37″ to 32° 08′ 11″ E longitudes and 25° 52′ 43″ to 26°04′ 38″ N latitudes). The total study area is about 41151.73 h representing nearly (97978.15 feddans) (feddan = 4200 m² = 0.420 hectares = 1.037 acres). Climate of the study area is classified as hot and recognized by long dry and very hot in summer while is cold in winter. On the other hand, the annual rainfall is very rare with high evaporation value (National Oceanic and Atmospheric Administration, 2019).

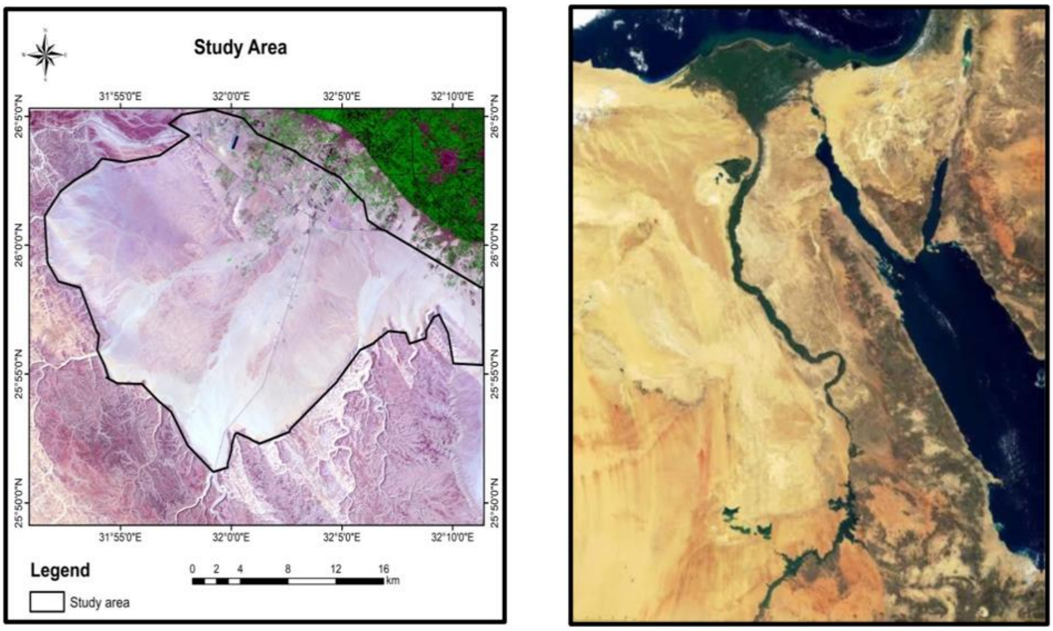

Figure (1): The location map of the study area.

2.2 Geomorphological features of the study area

The geomorphological units are recognized and delineated by analyzing the main landscape that extracted from the satellite image Landsat 8 (OLI) with the aid of the DEM and field study. The main geomorphological features found in the studied area include thirteen main units and each unit has its own characteristics. Table (1) and Figure (2) indicated that the geomorphological units of Wadi Samhoud area can be summarized as follows: alluvial fans, alluvial plain, basin, colluvial plain, high terraces, low terraces, moderate terraces, pedi plain, pediment plain, sand plain, table land, wadi (plain valley) and mesa.

Table (1): Geomorphological units of the study area.

Geomorphological unit	Representing soil profiles No.	Area (Hectares)	Area (m^2)	Area (Feddan)
Alluvial fans	11 and 29	3219.102	32190314.23	7664.4
alluvial plain	6, 21 and 24	4021.452	40213640.11	9574.7
Colluvial plain	28	2552.814	25527574.67	6077.9
Basin	3 and 9	2775.958	27758972.07	6609.3
High terraces	15, 16, 19 and 20	4907.17	49070607.86	11683.5
Low terraces	1, 2 and 4	2482.765	24827100.83	5911.2
Moderate terraces	17 and 18	4478.357	44782577.32	10662.5
Pedi plain	7, 14 and 22	4349.641	43495459.52	10356.1
Pediment plain	12, 13, 23, 25 and 26	4980.293	49801825.67	11857.6
Sand plain	8 and 10	3672.079	36719980.91	8742.9
Table land	27	1134.004	11339784.46	2699.9
Wadi (plain valley)	5	2372.14	23720873.61	5647.8
Mesa	-	205.9534	2059488.28	490.5
Total	-	41151.73	411508199.6	97978.15

Feddan = 4200 m^2 = 0.420 hectares = 1.037 acres.

2.3 Field and Laboratory work

Twenty-nine soil profiles were chosen to represent the different geomorphological units (except Mesa unit which is considered very rugged) that cover all the investigated area Figure (3). The locations of these soil profiles were recorded in the field using the Global Positioning System (GPS). These profiles were dug down to the suitable depth according to the nature of the soil material unless it was hindered by a bed rock or 150 cm. All soil profiles were morphologically described according to the standard procedure and terminology as reported by FAO (2006) and Schoenberger *et al*. (2012). Soil samples (109) were collected from different layers of all investigated soil profiles according to the morphological variations. The soil samples were air-dried, crushed, sieved through 2 mm sieve, and kept in plastic bags for physical and chemical analysis. Particle-size distribution was determined using pipette method (Piper, 1950). The soil organic matter content (SOM) was determined by Wakley and Black method (Jackson, 1973). The soil calcium carbonate ($CaCO_3$) was measured by calcimeter method according to Nelson (1982). Soil pH was measured in a 1:1 soil to water suspension (Mclean, 1982). The electrical conductivity of the soil saturated paste extract (EC_e) was measured according to Jackson (1973). Gypsum content was determined using the acetone method (Hesse, 1998). The cation exchange capacity (CEC) was measured according to Jackson (1973). The exchangeable sodium percentage (ESP) was calculated as a ratio from the cation exchange capacity (CEC) values. Available nitrogen was determined by micro Kieldahl and available potassium was measured using flamephotometer method (Jackson, 1973). Available phosphorus was determined using spectrophotometer method according to Olsen *et al*. (1954).

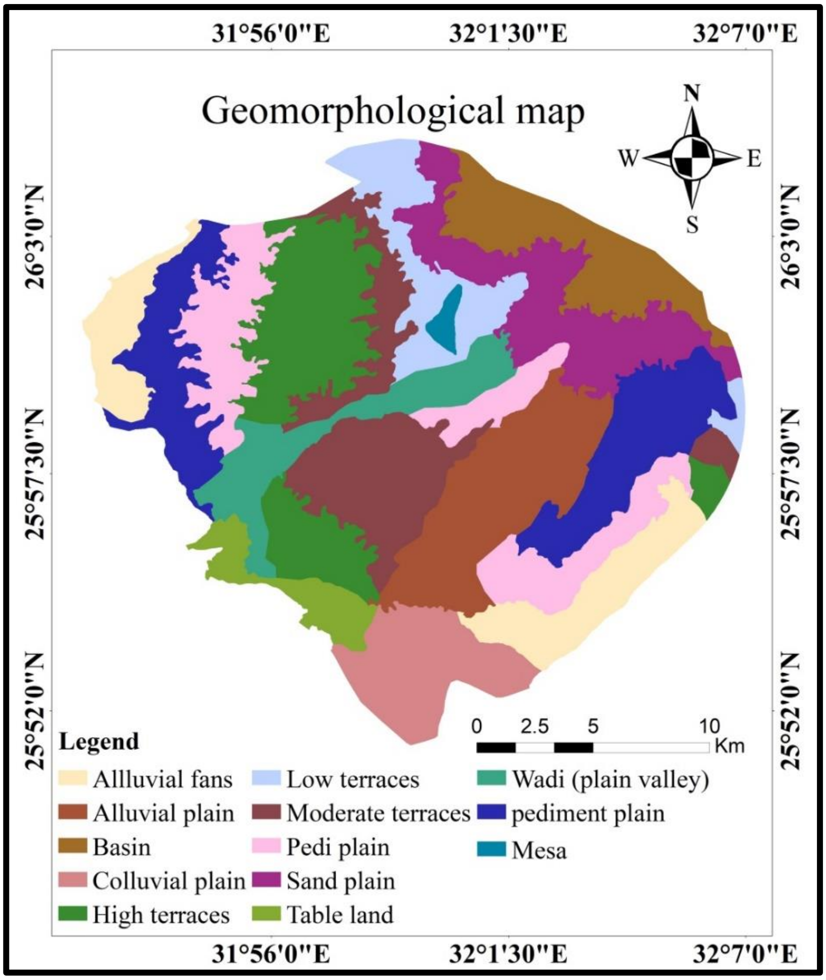

Figure (2): Geomorphological units of the study area.

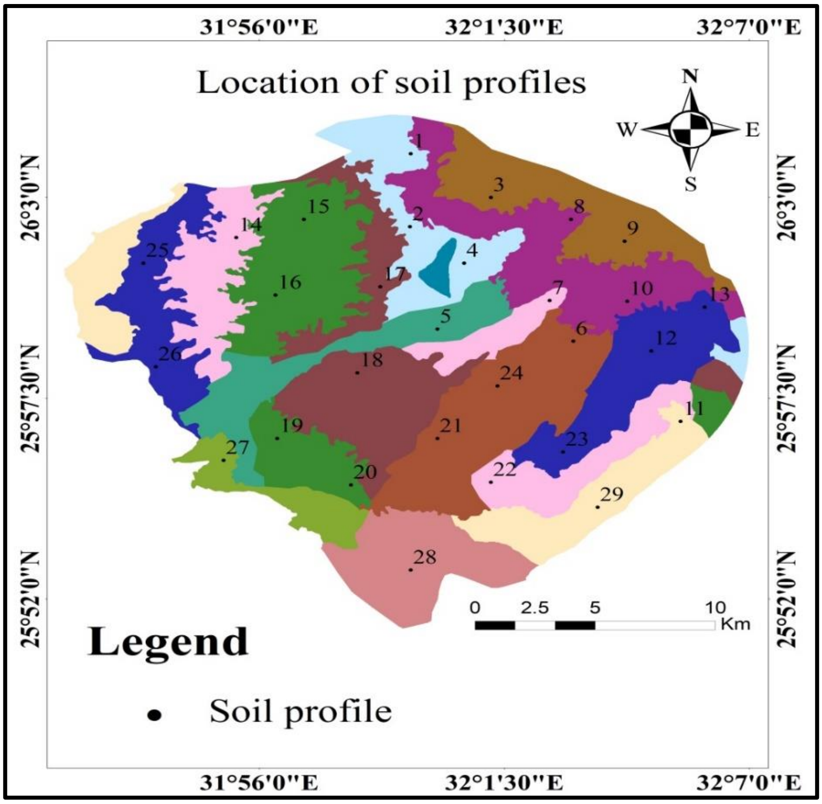

Figure (3): The location map of the soil profiles.

2.4 Remote sensing (Rs) and Geographic Information System (GIS)

Landsat 8 satellite images (path 176, row 39) covering the studied area were acquired on 19-9-2019. The ENVI 5.3 software was implemented (ITT, 2017). The location, geomorphological units, some soil properties, and suitability maps of the investigated soils were layout, annotated, projected, and finally produced using Arc GIS 10.4 software (ESRI, 2015).

2.5 Land suitability

The applied system of land evaluation (ASLE) for arid and semi-arid regions by Ismail and Morsi (2001) program was used to predict soil suitability for some field crops (maize, wheat and sugar beet), forage crops (alfalfa), vegetable crops (tomato, pepper and onion) and fruit trees (date palm and olive). The Micro LEIS (Almagra model) program was introduced by De la Rosa *et al*. (2004). Table (2) was used for selected crops such as wheat, maize, watermelon, potato, soya been, cotton, sunflower, sugar beet, alfalfa, peach, citrus and olive.

Table (2): Land suitability grades of the applied system of land evaluation (ASLE) and MicroLEIS (Almagra model).

Applied System of Land Evaluation (ASLE) program			Micro LEIS (Almagra model)					
Suitability class			Limitation				Soil factor	
Class	%	Description	Symbol	Definition	Symbol	Definition	Symbol	Definition
S1	< 80	High suitable	S1	High suitable	1	None	a	Sodium saturation
S2	60-80	Suitable	S2	Suitable	2	Slight	c	Carbonate
S3	30-60	Moderately suitable	S3	Moderately suitable	3	Moderate	d	Drainage
S4	20-30	Marginally suitable	S4	Marginally suitable	4	Severe	g	Profile development
NS1	10-20	Currently not suitable	S5	Not suitable	5	Very severe	p	Useful depth
							s	Salinity
NS2	<10	Permanently not suitable					t	Texture

3. Results and Discussion

3.1 Soil properties

Data in Table (3a,b) show that the saturation percentage (SP) of the studied soils ranges between 18.8 and 36.5, due to the coarse texture of these soils. Two soil texture categories are found in these soils; coarse texture which are represented by the sand and loamy sand texture grades and the moderately coarse texture that is sandy loam texture grade (Figure 4) according to Sys (1979). The soil organic matter content (SOM) is low (0.03 - 0.79%). Calcium carbonate ($CaCO_3$) content varies between 0.4 and 55.3% (Figure 5). Some soils are considered as calcareous soils ($CaCO_3$ > 15%). The gypsum content varies between 0.00 to 53.84% (Figure 5). The electrical conductivity of the saturated soil paste extract (EC_e) of these soils differed widely from 1.1 to 375.0 dS/m (Table 3a,b). Most of these soils are highly saline that have $EC_e > 16$ dS/m. The soil reaction (pH) varied from 7.7 to 9.1. The cation exchange capacity (CEC) varied between 5 and 15 cmol (+) /kg. The soil exchange sodium percentage ranges between 10 to 18. The soil fertility of the study area varied from low to moderate where the available nitrogen content is low to moderate (13-78 mg/kg), the available phosphorus varied between 1.7 and 15 mg/kg and the available potassium had low to moderate values of 66.5 and 332 mg/kg.

3.2 Land suitability

3.2.1 ASLE program

The land suitability classes for a few specific crops that may be grown in the study area utilizing the applied system of land evaluation (ASLE) program under sprinkler, and drip irrigation systems for some crops were selected to study the suitability of cultivation in the study area as shown in the Table (4).

Table (3a): Some chemical and physical properties of the studied profiles.

Profile No.	Depth (cm)	SP (%)	G.V (%)	Particle-size distribution Sand (%)	Silt (%)	Clay (%)	Texture grade	O.M (%)	$CaCO_3$ (%)	Gypsum (%)	ECe (ds/m)	pH (1:1)	CEC cmo(+)/kg	ESP (%)	Av.N (mg/kg)	Av.P (mg/kg)	Av.K (mg/kg)
1	0-20	19.5	12	83	14	3	Loamy sand	0.33	12.3	0.76	86.1	8.0	10	13	55	11	191
	20-70	20.8	8	83	13	4	Loamy sand	0.09	11.9	1.55	39.5	8.4	10	14	28	8	193
	70-90	20.0	44	87	10	3	Very gravelly loamy sand	0.06	11.1	1.02	79.1	8.0	7	17	22	4	111
	90-120	18.8	38	93	3	4	Very gravelly sand	0.30	3.8	0.56	54.3	8.1	11	12	49	8	116
	120-150	20.0	36	89	8	3	Very gravelly sand	0.30	3.4	0.94	30.5	8.4	8	16	47	8	125
2	0-30	36.5	13	91	7	3	Sand	0.79	1.3	1.63	16.6	7.7	12	10	78	15	207
	30-90	21.7	59	88	9	3	Very gravelly sand	0.27	8.5	0.02	2.6	8.9	7	15	45	5	110
	90-150	21.3	16	84	13	3	Gravelly loamy sand	0.12	7.7	0.00	2.2	9.0	8	11	31	5	125
3	0-20	23.0	32	88	7	5	Gravelly sand	0.27	6.4	1.07	26.0	8.1	9	18	40	11	166
	20-35	20.8	19	92	5	3	Gravelly sand	0.36	3.0	0.63	4.8	8.1	10	10	51	9	133
	35-80	20.5	59	85	12	3	Very gravelly loamy sand	0.21	7.2	0.60	5.1	8.3	12	12	43	5	157
	80-150	22.8	55	83	14	3	Very gravelly loamy sand	0.19	11.9	0.69	6.5	8.3	11	13	38	7	182
4	0-15	21.3	29	88	8	4	Gravelly sand	0.10	6.4	0.50	4.6	8.3	6	15	34	11	131
	15-35	21.8	2	86	10	4	Loamy sand	0.33	1.3	0.14	5.2	8.9	10	14	47	10	151
	35-90	22.3	60	86	10	4	Very gravelly loamy sand	0.36	2.6	0.73	8.9	8.3	13	11	52	8	145
	90-150	23.0	53	89	9	2	Very gravelly sand	0.21	1.7	0.75	9.4	8.4	9	16	41	10	103
5	0-25	22.8	21	92	5	3	Gravelly sand	0.21	6.0	0.60	3.6	8.3	8	13	42	10	87
	25-75	21.0	7	95	2	3	Sand	0.33	7.7	0.83	7.7	8.3	7	17	49	4	172
	75-150	23.0	45	93	3	4	Very gravelly sand	0.24	12.3	0.89	10.6	8.3	6	13	41	5	154
6	0-20	22.5	31	73	22	5	Gravelly sandy loam	0.30	14.5	1.40	38.9	8.4	10	14	58	11	293
	20-45	23.8	55	72	23	5	Very gravelly sandy loam	0.24	12.8	1.71	66.5	8.3	11	11	50	10	244
	45-95	22.3	57	78	17	5	Very gravelly loamy sand	0.44	13.6	1.69	70.2	8.3	8	14	60	9	200
	95-150	21.3	52	78	17	5	Very gravelly loamy sand	0.53	20.4	1.51	103.3	8.3	8	17	66	11	219
7	0-30	19.5	47	66	30	4	Very gravelly sandy loam	0.27	15.7	0.28	3.3	8.3	14	10	45	3	139
	30-80	20.3	43	94	2	4	Very gravelly sand	0.27	4.3	0.16	2.2	8.4	6	12	40	10	94
	80-120	21.5	55	89	8	3	Very gravelly sand	0.30	8.5	0.04	1.6	8.4	11	15	47	7	86
	120-150	20.0	53	90	6	4	Very gravelly sand	0.21	7.2	0.09	1.5	8.4	8	10	41	3	94
8	0-25	22.0	17	89	6	5	Gravelly sand	0.29	11.9	0.55	5.2	8.6	5	15	45	8	164
	25-50	21.3	10	92	4	4	Sand	0.44	10.2	0.59	5.3	8.6	7	11	51	10	172
	50-120	22.0	5	97	1	2	Sand	0.26	6.0	0.56	3.8	8.7	6	17	43	9	145
9	0-20	20.5	7	86	9	5	Loamy sand	0.41	12.3	0.65	11.8	8.3	10	14	56	12	238
	20-50	20.0	26	87	8	5	Gravelly loamy sand	0.32	12.8	0.37	33.5	8.2	10	12	51	8	164
	50-120	23.3	11	91	4	5	Sand	0.50	8.5	0.42	10.6	8.4	8	12	60	6	106
10	0-20	23.3	8	95	2	3	Sand	0.21	8.9	0.54	4.2	8.2	9	13	48	8	103
	20-70	25.0	4	77	19	4	Loamy sand	0.39	12.8	0.00	3.6	9.1	11	14	53	2	149
	70-150	26.3	3	93	4	3	Sand	0.18	14.9	0.68	5.8	8.4	8	17	29	4	113
11	0-10	23.5	2	87	10	3	Sand	0.03	10.0	0.23	3.2	8.6	10	12	19	6	100
	10_40	20.8	52	88	8	4	Very gravelly sand	0.12	11.5	0.89	10.3	8.4	9	11	25	9	160
	40-100	21.0	62	93	3	4	Very gravelly sand	0.30	22.6	1.01	14.5	8.4	11	18	59	7	144
	100-150	21.3	61	93	4	3	Very gravelly sand	0.45	16.6	0.25	5.1	8.5	5	16	60	4	106
12	0-20	20.5	5	95	2	3	Sand	0.18	11.1	0.15	3.8	8.5	10	13	39	7	149
	20-40	20.8	58	91	5	4	Very gravelly sand	0.42	14.9	0.60	13.1	8.3	7	17	52	12	121
	40-65	24.5	2	94	3	3	Sand	0.24	6.4	0.29	8.5	8.3	12	13	47	3	109
	65-110	23.8	26	92	5	3	Gravelly sand	0.45	12.3	0.66	10.1	8.3	9	11	56	8	94
	110-150	22.8	58	84	12	4	Very gravelly loamy sand	0.27	8.7	0.88	61.2	8.0	11	15	44	12	254
13	0-20	21.3	3	92	5	3	Sand	0.15	8.5	0.42	5.2	8.7	10	12	25	10	134
	20-65	21.8	33	95	2	3	Gravelly sand	0.30	9.4	0.74	6.5	8.6	9	14	48	7	121
	65-100	19.8	3	96	2	2	Sand	0.27	6.8	0.12	4.4	8.7	10	12	39	5	94
	100-150	19.3	45	97	1	2	Very gravelly sand	0.09	9.4	0.08	3.9	8.6	7	15	22	9	98
14	0-20	21.8	21	91	6	3	Gravelly sand	0.09	8.9	0.79	21.7	8.2	11	16	35	4	168
	20-80	29.5	9	59	29	12	Sandy loam	0.15	5.1	2.92	35.4	8.2	12	17	37	8	202
	80-120	33.2	50	59	38	2	Very gravelly sandy loam	0.30	10.6	3.62	42.8	7.7	14	18	51	15	166
	120-150	29.0	47	54	38	8	Very gravelly sandy loam	0.48	51.9	2.74	32.5	8.0	13	15	59	12	155

SP=Saturation percentage, G.V= Gravel by volume, O.M=Organic matter, $CaCO_3$ =Calcium carbonate, C.E.C = Cation, exchangeable capacity, Av. N= Available nitrogen, Av. P= Available phosphors, Av. K= Available potassium.

There is a broad range of suitability grades in the studied soils, from highly suitable (S1) to not suitable (currently not suitable (N1) and permanently not suitable, (N2)) as shown in Table (4) and illustrated in Figure (6a,b). Most of the investigated soils are marginally suitable for wheat, sugar beet, Maize, alfalfa, tomato, pepper and olive. Except some areas are not suitable (currently not suitable (N1) and permanently not suitable (N2)) for these crops. Few areas are suitable for tomato and olive while they are moderately suitable for maize, tomato, pepper and olive. On the other land, most of the study area is suitable for date palm and some area is highly suitable and few areas are moderately and marginally suitable for date palm.

Table (3b): Some chemical and physical properties of the studied profiles.

Profile No.	Depth (cm)	SP (%)	G.V (%)	Particle-size distribution			Texture grade	O.M (%)	$CaCO_3$ (%)	Gypsum (%)	ECe (ds/m)	pH (1:1)	CEC (cmo(+)/kg)	ESP (%)	Av.N (mg/kg)	Av.P (mg/kg)	Av.K (mg/kg)
				Sand (%)	Silt (%)	Clay (%)											
15	0 -15	25.5	12	77	18	5	Loamy sand	0.33	15.7	0.88	5.6	8.3	10	18	61	9	213
	15-35	23.0	5	61	36	3	Sandy loam	0.21	4.7	1.19	32.1	8.2	11	15	50	8	299
	35-90	26.8	59	81	10	9	Very gravelly loamy sand	0.18	12.8	1.07	57.6	8.0	10	17	42	5	158
	90-150	26.5	37	82	16	2	Very gravelly loamy sand	0.19	11.5	1.04	43.9	8.0	11	14	37	6	193
16	0-30	20.0	38	82	14	4	Very gravelly loamy sand	0.23	19.1	0.59	4.4	8.3	7	16	39	10	199
	30-65	23.8	11	86	9	5	Loamy sand	0.23	13.0	0.99	17.4	8.5	11	10	43	8	129
	65-85	24.5	53	87	8	5	Very gravelly loamy sand	0.26	25.5	0.64	13.5	8.5	10	12	44	6	194
	85-110	29.1	2	48	48	4	Sandy loam	0.05	6.4	2.39	21.8	8.5	13	16	16	9	277
	110-130	35.2	2	35	58	7	Silty loam	0.26	0.4	3.19	23.1	8.3	15	13	40	4	332
	130-150	28.7	3	51	46	3	Sandy loam	0.17	0.4	2.96	26.6	8.4	10	16	27	9	239
17	0-20	19.3	38	85	12	3	Very gravelly loamy sand	0.23	2.6	0.28	4.1	8.8	8	16	40	8	190
	20-60	27.5	6	70	27	3	Sandy loam	0.23	8.1	0.13	5.2	9.0	12	14	38	9	285
	60-130	29.1	4	62	33	5	Sandy loam	0.05	8.9	1.90	21.3	8.4	10	15	13	7	292
18	0-20	25.8	36	81	15	4	Very gravelly loamy sand	0.41	25.5	0.50	4.0	8.5	9	14	55	5	176
	20-65	27.3	44	73	22	5	Very gravelly sandy loam	0.38	41.3	0.09	2.2	8.7	12	17	50	9	283
	65-130	27.0	46	69	26	5	Very gravelly sandy loam	0.29	55.3	0.06	2.4	8.8	8	13	42	7	255
19	0-30	19.3	25	91	5	4	Gravelly sand	0.32	11.1	0.68	5.1	8.6	5	13	53	9	168
	30-50	19.3	23	94	3	3	Gravelly sand	0.41	7.7	0.66	6.5	8.6	6	11	55	8	133
	50-75	20.8	5	95	2	3	Sand	0.35	6.0	0.30	4.7	8.9	10	15	49	3	106
	75-140	21.8	2	94	3	3	Sand	0.38	5.1	0.22	6.7	9.0	6	13	45	6	66
20	0-25	20.3	20	86	9	5	Gravelly loamy sand	0.20	13.6	0.51	4.7	8.6	12	13	40	7	137
	25-50	21.3	5	96	1	3	Sand	0.35	3.4	0.11	3.4	8.8	6	18	48	5	102
	50-95	21.5	6	97	1	2	Sand	0.38	6.8	0.00	2.5	8.9	7	12	53	4	85
	95-150	19.8	9	96	1	3	Sand	0.29	6.4	0.18	2.7	8.7	6	16	46	5	74
21	0-30	28.0	7	74	21	5	Sandy loam	0.47	14.5	0.49	4.2	8.6	9	13	58	7	287
	30-50	28.3	9	78	19	3	Loamy sand	0.35	7.7	1.61	65.6	8.2	11	15	45	8	207
	50-90	33.3	4	66	28	6	Sandy loam	0.29	4.7	53.78	375.0	8.5	9	11	42	7	301
	90-150	20.5	3	76	18	6	Loamy sand	0.13	13.2	1.57	227.1	8.6	7	17	31	9	219
22	0-20	24.7	51	66	26	8	Very gravelly sandy loam	0.18	17.0	1.02	46.5	8.2	11	16	34	11	293
	20-70	30.0	65	68	27	5	Very gravelly sandy loam	0.48	5.5	1.39	29.6	8.3	12	10	62	9	271
	70-150	29.7	52	65	30	5	Very gravelly sandy loam	0.39	34.5	1.53	46.5	8.3	8	15	49	7	246
23	0-30	25.5	3	74	21	5	Sandy loam	0.36	11.9	0.78	7.8	8.3	12	13	42	10	307
	30-70	23.5	34	84	11	5	Gravelly loamy sand	0.30	14.0	0.12	3.6	8.8	11	18	41	8	149
	70-140	20.8	36	81	14	5	Very gravelly loamy sand	0.18	14.9	0.64	10.2	8.4	9	13	39	11	121
24	0-30	23.8	24	78	17	5	Gravelly loamy sand	0.15	18.3	1.06	53.2	8.1	11	12	39	7	195
	30-70	20.0	29	93	3	4	Gravelly sand	0.27	15.3	29.48	315.0	7.7	10	14	43	2	161
	70-120	24.0	34	82	14	4	Gravelly loamy sand	0.57	23.0	1.25	119.6	8.0	8	16	65	12	239
25	0-20	21.6	37	89	7	4	Very gravelly sand	0.38	14.0	0.39	3.9	8.5	8	11	43	9	94
	20-60	24.5	3	97	1	2	Sand	0.35	9.4	0.04	2.3	9.0	9	13	41	4	98
	60-130	29.0	40	87	9	4	Very gravelly loamy sand	0.29	4.7	0.76	8.7	8.5	10	17	40	8	102
26	0-20	19.5	29	89	7	4	Gravelly sand	0.35	8.5	0.20	3.6	8.7	7	10	51	7	90
	20-45	20.5	29	91	4	5	Gravelly sand	0.35	12.8	0.00	1.4	8.8	9	15	45	6	98
	45-90	21.8	4	95	2	3	Sand	0.38	9.8	0.00	1.5	8.9	6	18	49	6	84
	90-150	26.5	26	81	15	4	Gravelly loamy sand	0.41	25.5	0.00	1.6	9.0	9	14	53	8	170
27	0-20	19.5	51	91	4	5	Very gravelly sand	0.38	13.2	0.19	2.5	8.6	10	14	53	8	89
	20-45	19.0	42	93	3	4	Very gravelly sand	0.20	13.6	0.01	1.8	8.7	7	12	39	9	85
	45-85	20.0	2	89	9	2	Sand	0.17	5.1	0.00	1.2	8.9	11	13	23	3	91
	85-130	21.3	6	95	2	3	Sand	0.35	11.9	0.00	1.9	8.7	6	14	50	6	123
28	0-25	21.8	27	95	2	3	Gravelly sand	0.17	11.1	0.18	1.8	8.6	8	17	24	5	94
	25-50	20.5	41	96	1	3	Very gravelly sand	0.41	8.9	0.44	2.9	8.5	9	17	55	5	106
	50-85	23.8	3	93	4	3	Sand	0.29	8.1	0.00	3.3	8.7	7	12	41	7	99
	85-150	25.0	2	96	1	3	Sand	0.32	6.8	0.00	2.5	8.9	6	10	45	2	95
29	0-20	20.5	5	95	2	3	Sand	0.32	7.2	0.17	2.2	8.6	10	12	42	4	102
	20-50	21.3	4	96	1	3	Sand	0.20	22.6	0.00	1.1	8.8	9	14	33	6	147
	50-90	19.5	36	94	3	3	Very gravelly sand	0.32	7.7	0.14	2.7	8.8	11	14	53	2	98
	90-140	23.0	31	93	4	3	Gravelly sand	0.20	6.0	0.03	3.4	8.8	8	15	40	7	102

SP=Saturation percentage, G.V= Gravel by volume, O.M=Organic matter, $CaCO_3$ =Calcium carbonate, C.E.C = Cation, exchangeable capacity, Av. N= Available nitrogen, Av. P= Available phosphors, Av. K= Available potassium.

Table (4): Land suitability classes under sprinkler and drip irrigation systems of the study area for selected crops using ASLE program.

Profile No.	Field Crops			Forage Crops	Vegetables			Fruit Trees	
	Maize	Wheat	Sugar beet	Alfalfa	Tomato	Pepper	Onion	Date palm	Olive
1	NS1	NS2	NS2	NS2	S4	NS1	NS2	S4	S4
2	S3	S4	S4	NS1	S2	S3	NS1	S2	S2
3	S3	S4	S4	S4	S2	S3	S4	S2	S2
4	S3	S4	S4	S4	S2	S3	S4	S2	S2
5	S3	S4	S4	S4	S2	S3	NS2	S2	S2
6	NS1	NS2	NS2	NS2	NS2	NS1	NS2	S4	S4
7	S3	S4	S4	S4	S2	S2	S4	S1	S2
8	NS1	S4	S4	S4	S4	S4	S4	S2	S4
9	NS1	NS2	S4	NS2	S4	S4	NS2	S2	S4
10	S3	S4	S4	S4	S2	S2	S4	S1	S2
11	NS1	S4	S4	S4	S4	NS2	NS2	S1	S4
12	NS1	S4	S4	S4	S4	NS2	NS2	S2	S4
13	NS1	S4	S4	S4	S4	S4	S4	S2	S4
14	NS1	NS2	NS2	NS2	S4	NS1	NS2	S2	NS1
15	NS1	NS2	NS2	NS2	S4	NS1	NS2	S4	NS1
16	NS1	S4	S4	S4	S4	NS1	NS2	S2	S2
17	NS1	S4	S4	S4	S2	NS1	NS2	S2	S2
18	S3	S4	S4	S4	S2	S3	S4	S2	S2
19	NS1	S4	S4	S4	S4	S4	S4	S2	S4
20	NS1	S4	S4	S4	S4	S4	S4	S1	S4
21	NS1	NS2	NS2	NS2	S4	NS1	NS2	S4	S4
22	NS2	NS2	NS2	NS2	NS2	NS2	NS2	S4	NS2
23	S3	S4	S4	S4	S2	S2	S4	S2	S2
24	NS1	NS2	NS2	NS2	S4	S4	NS2	S4	S4
25	S3	S4	S4	S4	S2	S2	S4	S2	S2
26	NS1	S4	S4	S4	S4	S4	S4	S1	S4
27	S4	S4	S4	S4	S4	S4	S4	S1	S4
28	NS1	S4	S4	S4	S4	S4	S4	S2	S4
29	NS1	S4	S4	S4	S4	S4	S4	S1	S4

S1: Highly suitable (> 80%), S2: Suitable (60-80%), S3: Moderately suitable (30-60%), S4: Marginally suitable (20-30%), N1: Currently not suitable (10-20%), N2: Permanently not suitable (< 10%).

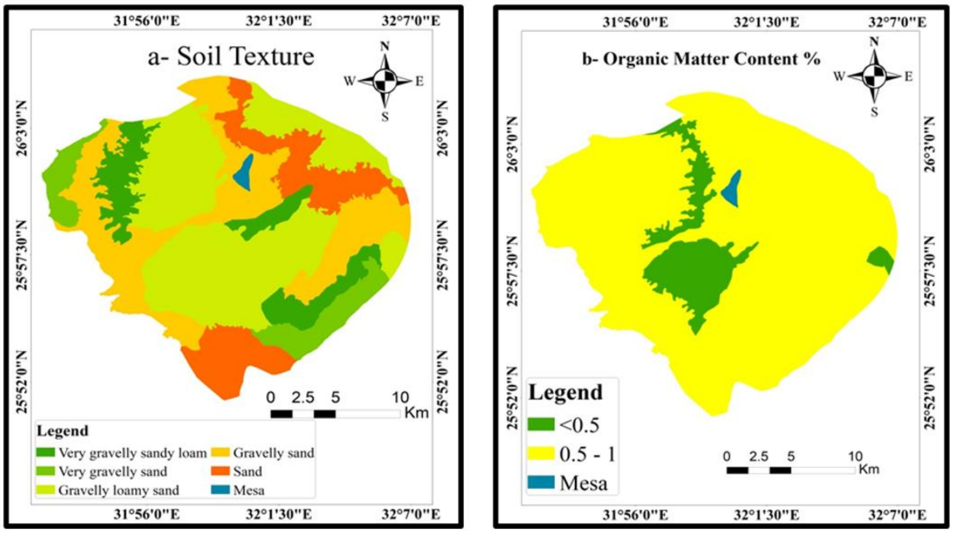

Figure (4): Spatial variability of a) the soil texture and b) Organic matter contents (OM %) in geomorphological units of the study area.

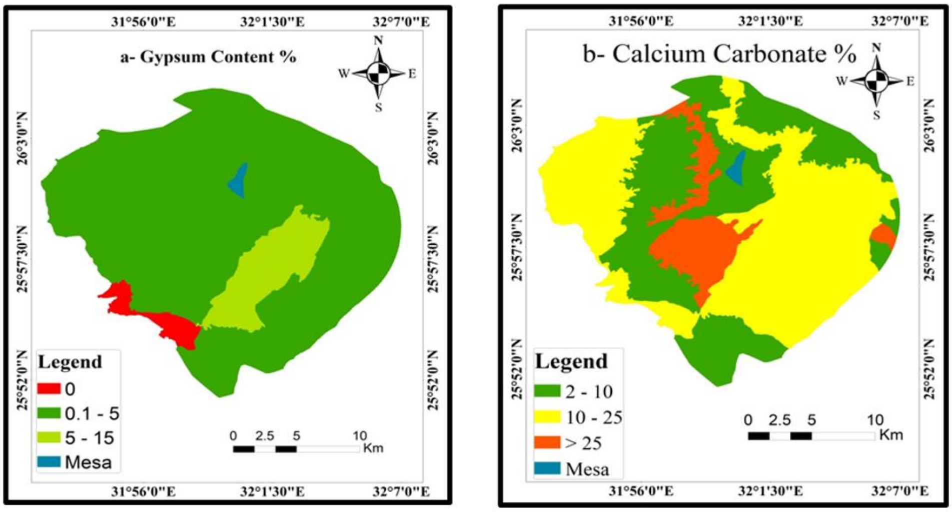

Figure (5): Spatial variability of a) gypsum contents (%) and b) soil calcium carbonate ($CaCO_3$%) in geomorphological units of the study area.

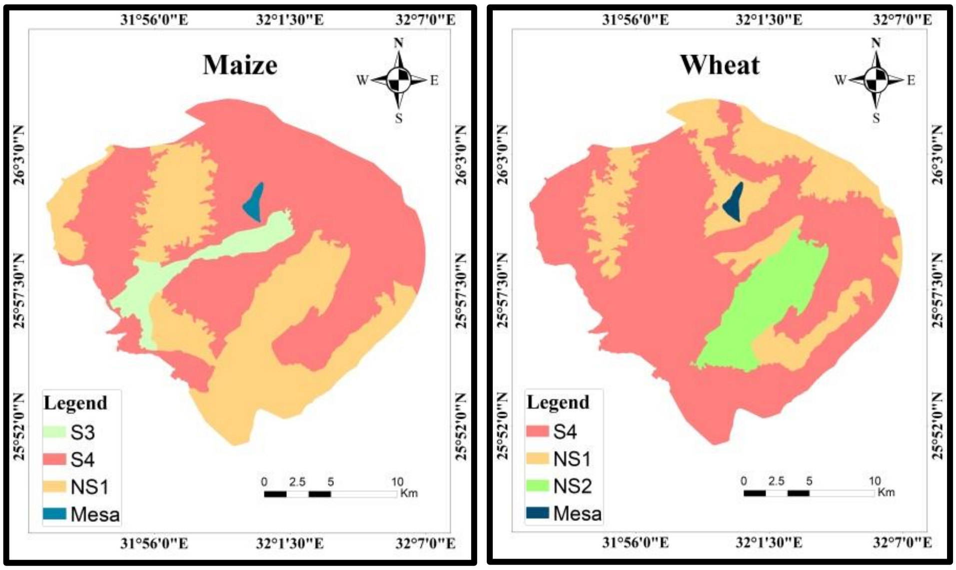

Figure (6a): Land suitability of the study area for selected crops using ASLE program under sprinkler, and drip irrigation systems of the study area.

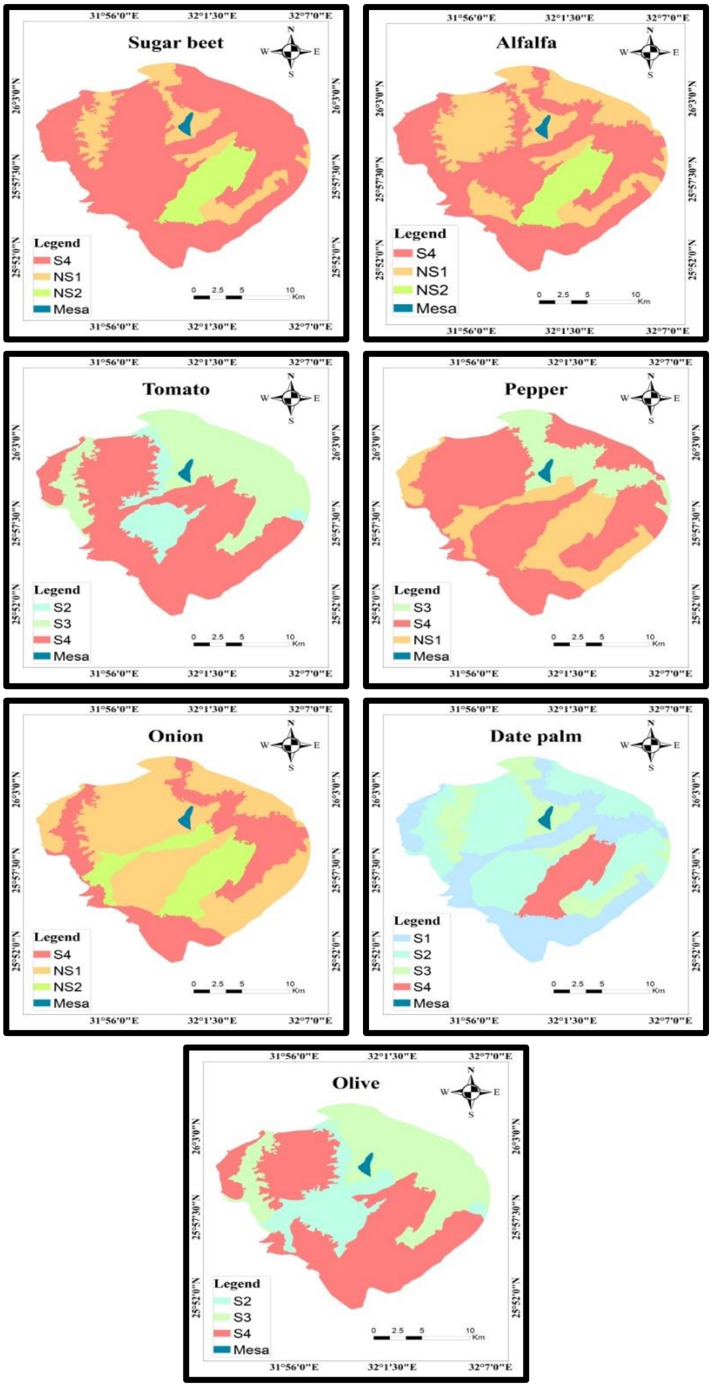

Figure (6b): Land suitability of the study area for selected crops using ASLE program under sprinkler, and drip irrigation systems of the study area.

3.2.2 MicroLEIS (Almagra model)

In general, the soils of the study area are varied between moderately suitable (3), marginally suitable (4) and not suitable (5) for the selected crops by using the microcomputer land evaluation information system (Micro LEIS-Almagra model). All soils of the study area not suitable for wheat, maize, watermelon, potato, soya been, cotton, sunflower, sugar beet and alfalfa. On the other side, some soils are marginally suitable for peach, citrus and olive. Few areas are moderately suitable for olive as shown in Table (5) and Figure (7a,b). The soil limitations of the current study are soil texture, soil salinity, calcium carbonate and soil fertility.

Table (5): Land suitability classes using Micro LEIS (Almagra model) program of the study area.

Profile No.	Wheat	Maize	Watermelon	Potato	Soya been	Cotton	Sunflower	Sugar beet	Alfalfa	Peach	Citrus	Olive
1	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
2	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3ts
3	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5s	S5s	S3ts
4	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4ts	S4ts	S3ts
5	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5s	S5s	S3ts
6	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s
7	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3t
8	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
9	S5ts	S5ts	S5ts	S5ts	S5ts	S5t	S5ts	S5t	S5t	S5s	S5s	S5s
10	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
11	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5ts	S5ts	S4t
12	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s
13	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S3ts
14	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
15	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s
16	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s	S5s	S5s
17	S5ts	S5ts	S5ts	S5ts	S5ts	S5t	S5ts	S5t	S5t	S5s	S5s	S5s
18	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t	S4t	S4t
19	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S4t	S3ts	S3ts	S3s
20	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
21	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s	S5s	S5s
22	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s	S5s	S5s
23	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4ts	S4ts	S4ts
24	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5ts	S5s	S5s	S5s
25	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
26	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
27	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
28	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t
29	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S5t	S4t

S3: Moderately suitable, S4: Marginally suitable, S5: Non-suitable, t: soil texture, s: salinity.

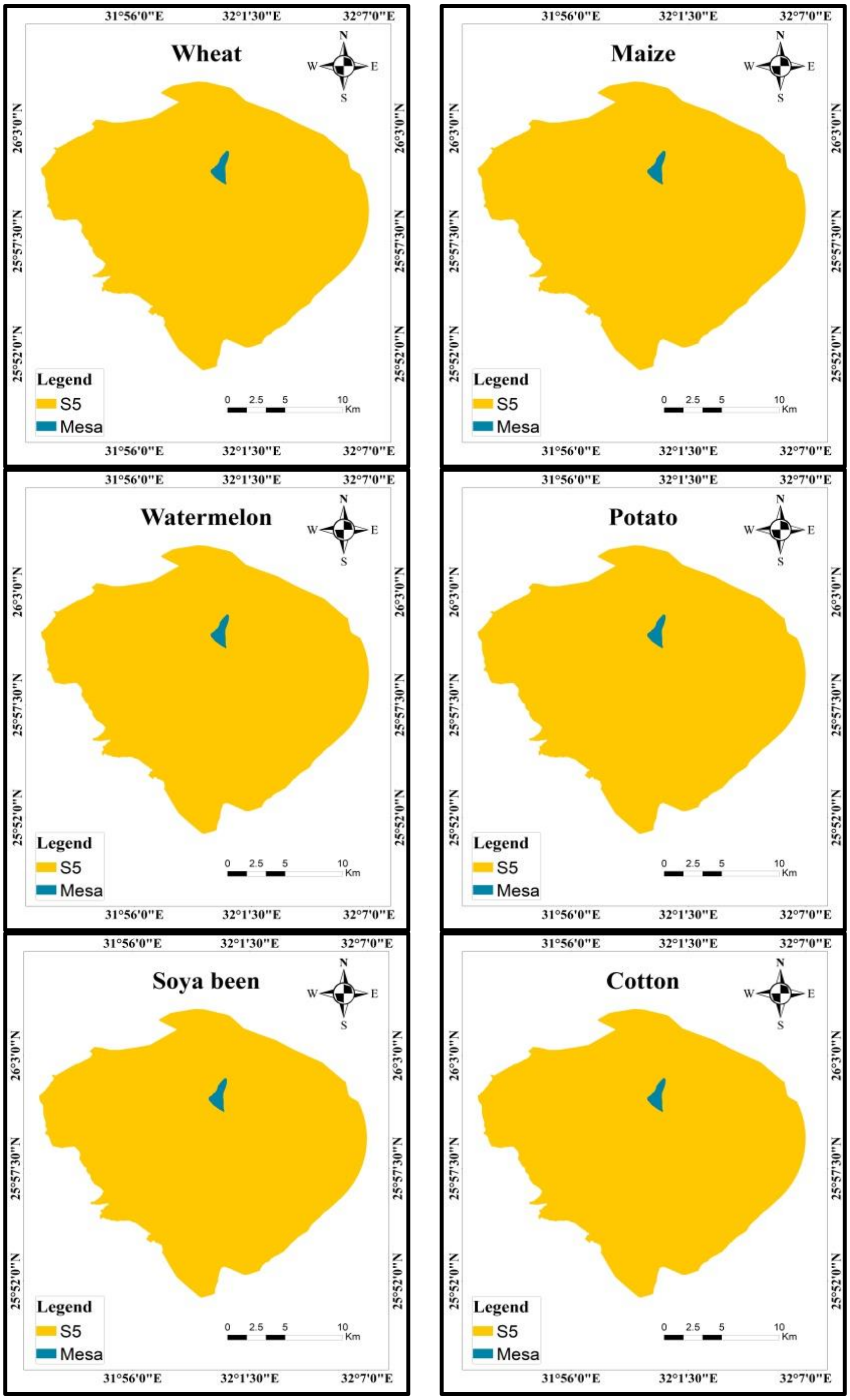

Figure (7a): Land suitability of the study area for some selected crops using MicroLEIS (Almagra model).

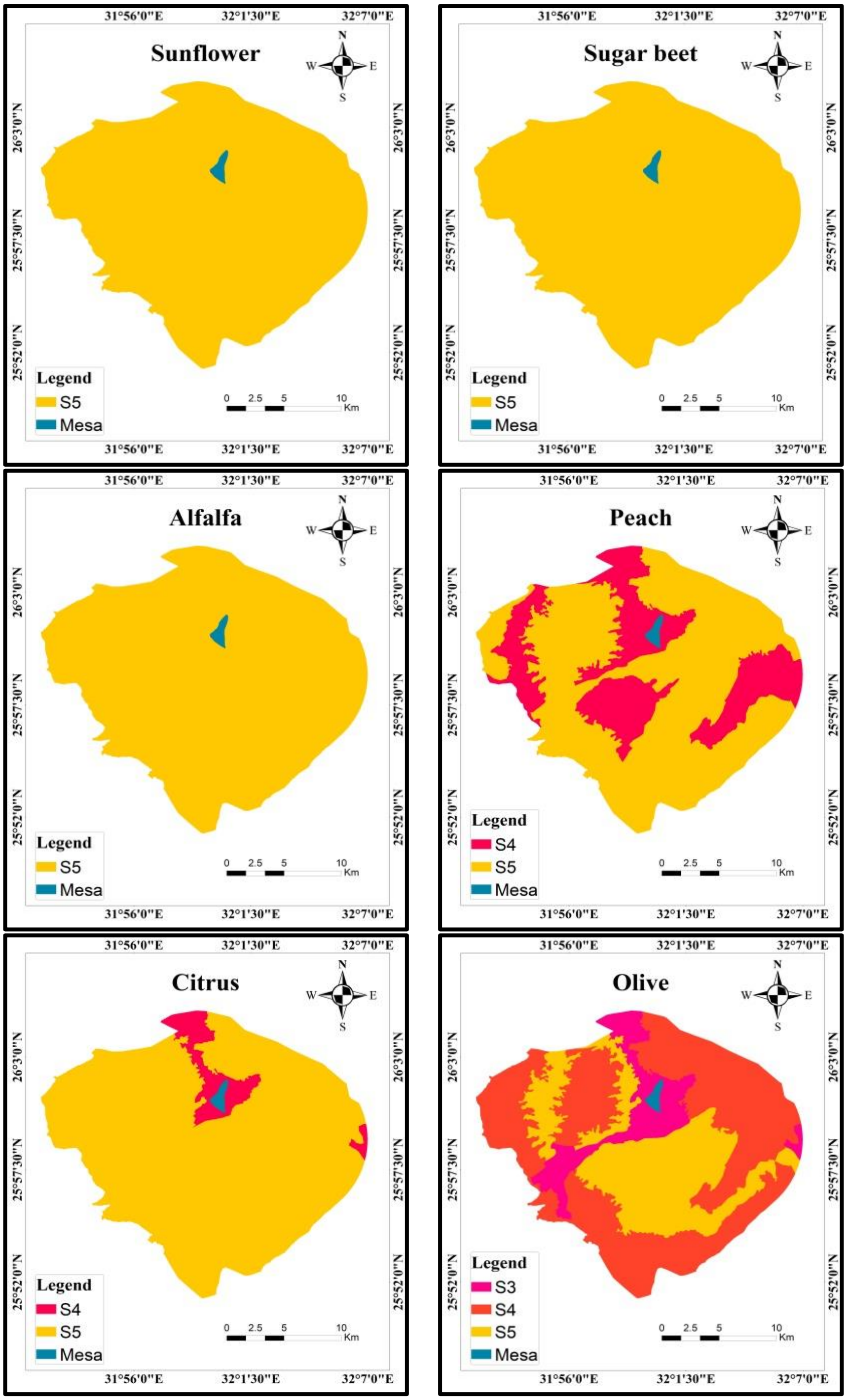

Figure (7b): Land suitability of the study area for some selected crops using MicroLEIS (Almagra model).

4. Conclusion

The assessment of soil suitability for the chosen crops using ASLE and micro LIES programs are very important for soil management and sustainable agricultural programs. The main soil limitations of the area under study are coarse soil texture, soil salinity, calcium carbonate and low soil fertility characteristics. These soil limitations can be improved using good management practices, such as adding agricultural gypsum, organic matter and fertilizers to upgrade the fertility, leaching the excess salt, and good agriculture practices for crops. The potential appropriateness will grow as a result of these procedures.

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