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Land capability and suitability of some soils at North-West of Dashlut, Assiut, Egypt

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Abstract

Twelve soil profiles representing North-West of Dashlut area, Assiut, Egypt were selected and dug, and 43 soil samples were collected from these profiles to evaluate its productive capability and suitability for growing selected crops. The soils of this area had a coarse texture grades (sand, loamy sand, and sandy loam). Most of these soils were highly saline (EC_e > 16 dS/m) and showed low values of organic matter and available NPK, some of these soils are considered as calcareous. Tow modern programs including the applied system of land evaluation (ASLE) and the microcomputer land evaluation information system (MicroLEIS) were applied to assess the capability of these soils and their suitability to grow selected crops. The results of land capability showed that the soils of the study area were poor (C4), very poor (C5), and non-agricultural (C6) using the ASLE program, while the MicroLEIS (Cervatana model) program pointed that soils had moderately (S3) and marginally (N1) capable grades. Moreover, using the ASLE program, the soils of the study area 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 MicroLEIS (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. The geostatistics approach performed with ordinary kriging interpolation and semivariogram was applied to create a detailed and spatialized map for each soil parameter. Circular, J-Bessel, J-Bessel, and Stable geostatistical models were used to define the spatial variability of soil parameters based on RMS, MSE, and RMSSE. The main soil limitations of these soils were soil texture, soil salinity, and low soil fertility. However, these soil limitations are none permanent and can be improved through applying suited management practices.

Keywords: land capability, land suitability, MicroLEIS program, ASLE program.

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1. Introduction

Land suitability indicates that the ability of a portion of land to tolerate the production of crops in a sustainable way (Bandyopadhyay *et al*., 2009). Land suitability evaluation provides information on the restrictions and opportunities for land use and therefore, it guides decisions on resources optimal use. Knowledge is an essential prerequisite for land use planning and development. Furthermore, such a type of analysis helps to identify the major limiting factors for agricultural production and enables decision-makers such as land-use planners, land users, and agricultural support services to develop the management of crops able to overcome such constraints, increasing productivity. Land could be categorized into spatially distributed agriculture potential zones based on the soil properties, terrain characteristics, and analyzing present land use (AbdelRahman *et al*., 2016). According to FAO (2006), land suitability is the classification operation of soil to use appropriately. This operation is the evaluation and gathering of specific areas of land in terms of their suitability for defined uses. Geostatistical techniques can give more dependable, useful, and efficient tools to predict soil properties in unknown and unsampled sites and to describe the spatial association of data by variogram analyses (Webster and Oliver, 2007). The kriging is the most effective and strong interpolation method used in geostatistical applications (Mevlut, 2016). De la Rosa *et al*. (2004; 2009) designed the program of the Microcomputer Land Evaluation Information System (MicroLIES) package that has been considered a user-friendly agro-ecological decision support system for sustainable land use and management. The MicroLIES with a Cervatana and Almagra models forecast the general land capability or suitability for a broad series of possible agricultural uses. The program works interactively, comparing the values of the characteristics of the land unit with the generalization levels designated for each use capability class. The prediction of the general land use capability (Cervatana model) and the land suitability (Almagra model) are the results of a qualitative evaluation process or overall interpretation of the following biophysical factors such as relief, soil, climate, and current use or vegetation. Also, an Applied System for Land Evaluation (ASLE) program is proposed by Ismail and Morsi (2001) and Ismail *et al*. (2001) to evaluate land capability and suitability. This program calculates the final land capability index as a percentage value and the land suitability depends upon four characteristics, namely soil properties, irrigation water quality, soil fertility factors, and environmental parameters. Each factor was described as an index value to give its status in the percentage form (Marei *et al*., 1987; Zamil *et al*., 2009). Fadel and Sayed (2020) evaluated the soils of El-Qusiya area, Assiut, Egypt as one of the newly reclaimed areas using Storie index (O'GEEN, 2008). Their output data showed that these soils were fair (Grade 3) and poor (Grade 4) with slope and other soil limitation factors. MicroLIES-Cervatana model results showed that the land capability classes of this area were good (S2), moderate (S3), and marginal (N) with limiting factors of soil (i), erosion risks (r), and bioclimatic deficit (b). According to Sys and Verheye (1978) system, two land suitability classes, namely marginal suitable (S3) with severe limitations and presently not suitable (N1) were reported for this area. The land suitability of this area for growing different crops according to MicroLIES-Almagra model belonged to suitability classes of high suitable (S2), moderately suitable (S3), marginally suitable (S4), and not suitable (S5) for wheat, maize, watermelon, potato, soybean, cotton, sunflower, sugar beet, alfalfa, peach, citrus, and olive, with limitation factors of texture (t), drainage (d), carbonate (c), salinity (s), sodium saturation (a), and profile development (g). North-West of Dashlout area, Assiut, Egypt is considered one of the promising areas for agricultural expansion, due to its almost flat surface, neighbor of the residential areas, and its proximity to the main roads. So, the current study aims to assess the productive capacity of these lands and their suitability for growing various crops and define the main limitations of this study area.

2. Materials and methods

2.1 Study Area

The study area is located at North-West of Dashlut, Assiut, Egypt between latitude 27° 34′ 34.4″ to 27° 39′ 12.5″ N and longitude 30° 35′ 45.3″ to 30° 40′ 15.1″ E. It covers an area of 43.94 km^2 (10462 feddans). Twelve soil profiles were chosen to represent the study area (Figure 1) to evaluate the capability and suitability of these soils for the growth of crops and define the limiting factors of this area. Forty-three soil samples were collected from these soil profiles. Locations of these soil profiles were recorded in the field with GPS guidance. Each soil profile was dug to 130 -150 cm according to the type and nature of the soil material. The morphological description of these soil profiles was performed according to Soil Survey Staff (1993) and FAO (2006). The climate of this area was a thermic temperature regime and an aridic soil moisture regime where the mean annual temperature, rainfall, and relative humidity are 26 ˚C, 1.2 mm, and 40 %, respectively.

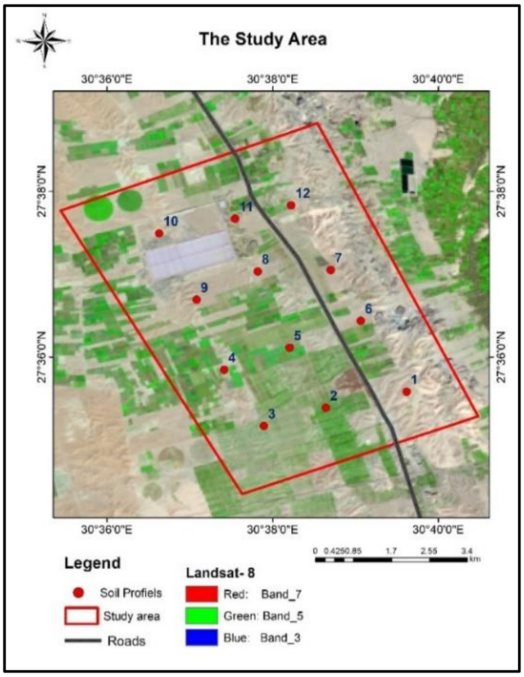

Figure (1): Location map of the study area.

2.2 Soil Analysis

The soil samples were air-dried, crushed, sieved through 2 mm sieve, and kept for physical and chemical analysis. In these samples, the particle-size distribution was determined by pipette method (Piper, 1950) and the saturated hydraulic conductivity was measured in the undisturbed soil cores using the constant head method (Kulte and Dirksen, 1986). The soil organic matter content (SOM) was determined by Wakley and Black method (Jackson, 1973). The soil calcium carbonate ($CaCO_3$) was measured by the 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 determined according to Jackson (1973). Gypsum content was determined using the acetone method (Hesse, 1998). The cation exchange capacity (CEC) was measured (Jackson, 1973). The exchangeable sodium percentage (ESP) was calculated using the values of CEC and the exchangeable sodium. Available nitrogen using Kjeldahl method (Hesse, 1998), available phosphorus using Olsen and Sommers (1982), and available potassium using flame photometer (Hesse, 1998) were determined in the collected soil samples. Landsat 8 satellite images (path 176, row 39) covering the studied area were acquired on 19-06-2020. The ENVI 5.1 software was implemented (ITT, 2017). The location, some soil properties, land capability, and suitability maps of the investigated soils were layout, annotated, projected, and finally produced using Arc GIS 10.2.2 software (ESRI, 2014).

2.3 Land Capability

The applied system of land evaluation (ASLE) program proposed by Ismail and Morsi (2001) was used to define the capability classes, C1, C2, C3, C4, C5, and C6 (Table 1). MicroLEIS (Cervatana model) internet-based program (De la Rosa et al., 2004) that has class S1, S2, S3, and N was also applied for land capability (Table 1).

Table (1): Land capability classes of the applied system of land evaluation (ASLE) and MicroLEIS (Cervatana model).

Applied System of Land Evaluation (ASLE) program		MicroLEIS (Cervatana model)	
Class	%	Class	Description
1	80-100 (Excellent)	S1	Excellent
2	60-80 (Good)	S2	Good
3	40-60 (Fair)	S3	Moderate
4	20-40 (Poor)	N	Marginal
5	10-20 (Very poor)		
6	<10 (Non-agricultural)		

2.4 Land Suitability

The applied system of land evaluation (ASLE) for arid and semi-arid regions (Ismail and Morsi, 2001) program based on the ratings of crop requirements proposed by Sys et al. (1993) was applied for different crops such as cotton, sunflower, sugar beet, wheat, barley, sugarcane, faba bean, maize, soya bean, rice, peanut, alfalfa, sorghum, vegetables, watermelon, pepper, tomato, cabbage, pea, onion, potato, date palm, fig, olive, grape, apple, pear, citric and banana (Table 2). The MicroLEIS (Almagra model) program introduced by De la Rosa *et al*. (2004) was used for selected crops such as alfalfa, cotton, sugar beet, maize, wheat, melon, potatoes, olive, soya bean, sunflower, citrus, and peach (Table 2).

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

Applied System of Land Evaluation (ASLE) program			MicroLEIS (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
NS2	<10	Permanently not suitable					s	Salinity
							t	Texture

2.5 Geostatistical analyses

The variability of the soil parameters was examined using the geostatistical approach. The geostatistical approach included the calculation of the experimental semivariogram and un-sampled site prediction. The most advantage of geostatistics is the measuring of the spatial correlation using the semivariogram. There are different models in geostatistical analysis, including circular, spherical, tetra-spherical, pentaspherical, exponenttial, gaussian, rational quadratic, hole effect, K-bessel, J-bessel, and stable. The suitability and validation of each model were examined through some parameters like mean prediction errors (MPE), root mean square prediction errors (RMSPE), mean standardized prediction errors (MSPE) that must be close to 0 and root mean square standardized prediction errors (RMSSPE) that should be close to 1 (Webster and Oliver, 2007).

3. Results and Discussion

3.1 Soil characteristics

The results show that the saturation percentage (SP) of the soil samples ranges between 18 to 28 %, due to the coarse texture of these soils (Table 3). Two soil texture categories are found in these soils including the coarse texture which is represented by the sand and loamy sand texture grades and the moderately coarse texture that is represented by the sandy loam texture grade according to (Sys, 1979). The hydraulic conductivity of these soil samples differs from 4.4 to 16.8 cm/h. The calcium carbonate content varies between 3 and 28%. Some soils of the study area are considered as calcareous soils (16-28 %). The soil organic matter (OM) is low 0.07-0.56% and the gypsum content reaches 0.74 % (Figure 2).

Table (3): Some soil physical properties of the study area.

Profile No.	Deep of layer	SP (%)	Gravel by volume (%)	Particle-size distribution Clay (%)	Silt (%)	Sand (%)	Texture grade	Hydraulic conductivity (cm/h)	$CaCO_3$ (%)	O.M (%)	Gypsum (%)	Land use
1	0-20	18	11	4	8	88	Sand	12.5	16	0.48	0.74	None
	20-50	21	5	8	9	83	Loamy sand	8.8	13	0.31	0.12	
	50-90	25	19	8	18	74	Gravelly sandy loam	5.1	9	0.37	0.53	
	90-150	23	25	5	15	80	Gravelly loamy sand	6.0	25	0.27	0.50	
2	0-30	20	20	2	6	92	Gravelly sand	10.0	6	0.34	0.00	Wheat, Tomato, Eggplant
	30-70	23	4	7	14	79	Loamy sand	6.0	7	0.37	0.00	
	70-130	19	19	5	7	88	Gravelly sand	9.3	5	0.29	0.01	
3	0-15	23	21	6	14	80	Gravelly loamy sand	6.7	11	0.43	0.03	None
	15-55	19	16	4	5	91	Gravelly sand	11.8	9	0.26	0.11	
	55-105	21	11	8	8	84	Loamy sand	8.2	14	0.33	0.19	
	105-150	20	13	5	6	89	Sand	11.9	17	0.24	0.02	
4	0-20	21	17	7	12	81	Gravelly loamy sand	7.4	9	0.49	0.02	None
	20-70	23	11	12	20	68	Sandy loam	4.5	15	0.21	0.01	
	70-110	20	19	4	7	89	Gravelly sand	9.9	11	0.19	0.03	
	110-150	25	8	10	21	69	Sandy loam	5.9	16	0.22	0.15	
5	0-30	19	9	5	4	91	Sand	12.9	10	0.55	0.00	Wheat, Onion, Pepper
	30-80	24	17	10	18	72	Gravelly sandy loam	4.6	28	0.49	0.01	
	80-140	28	17	8	28	64	Gravelly sandy loam	4.5	26	0.34	0.02	
6	0-25	19	7	4	6	90	Sand	14.7	9	0.35	0.01	None
	25-60	24	11	8	20	72	Sandy loam	6.8	10	0.32	0.01	
	60-90	20	19	3	6	91	Gravelly sand	11.4	4	0.17	0.02	
	90-150	23	16	7	19	74	Gravelly sandy loam	6.4	5	0.07	0.01	
7	0-30	20	11	6	4	90	Sand	10.9	3	0.32	0.00	Tomato, Onion, Pepper
	30-80	19	5	2	6	92	Sand	14.4	6	0.43	0.00	
	80-140	23	4	7	9	84	Loamy sand	10.9	5	0.29	0.01	
8	0-25	27	7	11	21	68	Sandy loam	5.5	11	0.30	0.00	None
	25-70	20	9	4	6	90	Sand	14.4	9	0.32	0.03	
	70-100	19	22	3	7	90	Gravelly sand	8.7	17	0.27	0.03	
	100-150	21	11	5	16	79	Loamy sand	9.7	15	0.22	0.02	
9	0-30	20	14	3	8	89	Sand	13.5	13	0.40	0.00	None
	30-80	24	8	9	21	70	Sandy loam	6.5	20	0.26	0.03	
	80-140	20	19	6	13	81	Gravelly loamy sand	6.8	10	0.25	0.03	
10	0-30	19	14	3	4	93	Sand	13.6	14	0.28	0.00	None
	30-90	23	7	7	33	60	Sandy loam	6.2	16	0.41	0.01	
	90-140	22	2	5	13	82	Loamy sand	13.0	11	0.37	0.11	
11	0-30	19	9	4	7	89	Sand	13.5	6	0.38	0.00	Tomato, Onion
	30-70	20	6	3	4	93	Sand	16.8	8	0.48	0.00	
	70-120	21	23	5	18	77	Gravelly Loamy sand	6.8	10	0.34	0.00	
	120-150	21	3	8	9	83	Loamy sand	9.9	14	0.29	0.01	
12	0-25	23	13	13	17	70	Sandy loam	4.4	11	0.56	0.02	Wheat, Tomato, Onion, Pepper
	25-55	22	11	8	14	78	Loamy sand	7.3	15	0.34	0.01	
	55-110	25	12	9	31	60	Sandy loam	4.8	10	0.49	0.02	
	110-150	19	9	3	7	90	Sand	16.8	16	0.22	0.01	

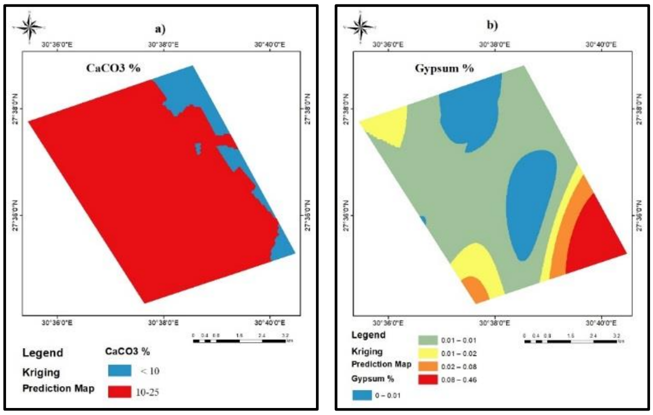

Figure (2): Spatial variability of a) the soil calcium carbonate ($CaCO_3$) and b) gypsum contents of the study area.

The electrical conductivity of the saturated soil paste extract (EC_e) of these soils ranges widely from 3.1 to 119.1 dS/m (Table 4). Most of these soils are highly saline that have EC_e> 16 dS/m (Figure 3). The soil pH of these soils varies from 7.1 to 9.4. The cation exchange capacity (CEC) is between 3 and 18 cmol (+) /kg. It has low values due to the prevailing coarse texture and the low colloid fraction of these soils. However, most of the study area has a soil exchange sodium percentage that is less than 15%.

Table (4): Some soil chemical characteristics of the study area.

Profile No.	Deep of layer	pH 1:1	EC_e dS/m	Cations (mmol/kg)				Anions (mmol/kg)			CEC cmol(+)/kg)	ESP (%)	Available nitrogen (mg/kg)	Available phosphorus (mg/kg)	Available potassium (mg/kg)
				Na^{+1}	Ca^{+2}	Mg^{+2}	K^{+1}	Cl^{-1}	SO_4^{-2}	CO_3^{-2} $+HCO_3^{-1}$					
1	0-20	7.8	119.1	136	27	8	4	184	13	0.5	15	14	45	6	126
	20-50	8.1	88.6	109	30	5	2	172	6	0.4	10	13	39	3	112
	50-90	7.7	103.4	185	26	7	4	223	16	0.4	12	15	43	3	78
	90-150	7.6	104.8	160	26	9	4	210	14	0.5	9	16	21	4	66
2	0-30	7.9	5.4	4	2	1	1	8	1	0.4	11	9	40	7	101
	30-70	9.4	3.1	4	1	0	0	6	1	0.2	12	8	40	9	69
	70-130	8.2	10.9	10	3	2	1	17	1	0.6	10	10	25	6	78
3	0-15	8.0	38.2	67	6	2	2	79	3	0.3	14	15	45	8	67
	15-55	9.1	31.7	36	8	2	1	46	5	0.6	9	11	38	7	95
	55-105	8.6	57.3	82	14	3	1	102	8	0.4	11	13	43	5	68
	105-150	8.4	44.2	57	10	3	2	81	3	0.8	8	14	23	5	55
4	0-20	8.2	41.8	49	14	4	2	80	2	0.4	16	12	50	6	44
	20-70	8.5	23.3	35	6	2	1	46	2	0.7	7	8	16	7	89
	70-110	8.9	55.4	56	17	8	2	101	3	0.6	7	14	17	4	56
	10-150	8.8	89.9	116	37	13	4	204	8	0.5	8	16	12	5	55
5	0-30	8.2	3.3	2	1	1	0	5	0	0.6	17	9	55	5	51
	30-80	8.0	26.9	39	6	5	2	58	2	0.4	16	8	46	2	126
	80-140	7.9	33.8	61	9	4	2	84	3	0.8	11	11	40	4	123
6	0-25	7.1	24.9	23	7	4	2	41	2	0.3	11	6	40	13	78
	25-60	7.8	23.3	28	10	2	2	48	2	1.4	11	6	38	8	90
	60-90	7.9	20.1	24	4	3	1	34	3	0.3	6	8	12	5	71
	90-150	7.8	12.9	13	5	2	1	26	1	0.3	3	12	11	6	59
7	0-30	8.3	3.2	3	1	0	1	5	1	0.4	11	9	39	7	106
	30-80	8.5	13.3	18	2	1	1	21	1	0.5	14	8	42	9	67
	80-140	7.7	27.4	34	11	2	1	56	2	0.5	10	7	37	6	93
8	0-25	8.4	17.2	26	7	2	2	43	1	0.8	10	5	40	7	56
	25-70	7.9	23.4	22	6	4	2	39	3	0.8	11	6	32	6	78
	70-100	8.7	41.5	45	12	3	2	70	3	0.6	9	12	34	8	82
	100-150	8.9	39.8	48	11	3	2	77	3	0.6	8	11	27	4	112
9	0-30	8.2	10.7	13	3	1	1	18	1	0.4	13	9	39	6	72
	30-80	8.5	45.6	55	19	6	3	99	4	0.7	9	11	34	8	95
	80-140	8.4	51.4	47	19	6	3	95	3	0.8	8	12	28	4	102
10	0-30	8.3	33.5	31	9	5	2	59	2	0.6	9	8	26	8	67
	30-90	8.7	66.2	75	24	10	4	146	2	0.5	13	16	42	4	79
	90-140	8.6	83.5	98	30	8	4	167	6	0.4	12	15	44	5	88
11	0-30	8.2	4.1	3	1	1	0	6	1	0.2	12	14	39	9	49
	30-70	8.1	11.4	13	3	1	1	20	1	0.6	15	9	41	3	115
	70-120	8.9	18.1	21	6	2	1	34	1	0.8	11	5	38	10	133
	20-150	9.1	24.8	32	6	2	1	47	1	0.6	10	8	26	8	78
12	0-25	8.2	22.7	29	6	4	2	45	2	0.5	18	6	57	10	149
	25-55	8.0	18.9	23	4	3	2	34	2	0.4	11	5	34	10	124
	55-110	8.9	55.4	77	23	5	3	129	3	1.0	16	15	41	5	78
	110-150	8.3	33.6	33	10	4	2	58	2	0.6	8	9	26	4	67

The soil fertility of the study area is low where the available nitrogen content is low (11-57 mg/kg), the available phosphorus varies between 2 and 13 mg/kg and the available potassium has low values of 44 and 149 mg/kg. Therefore, these soils need NPK fertilizers to be added.

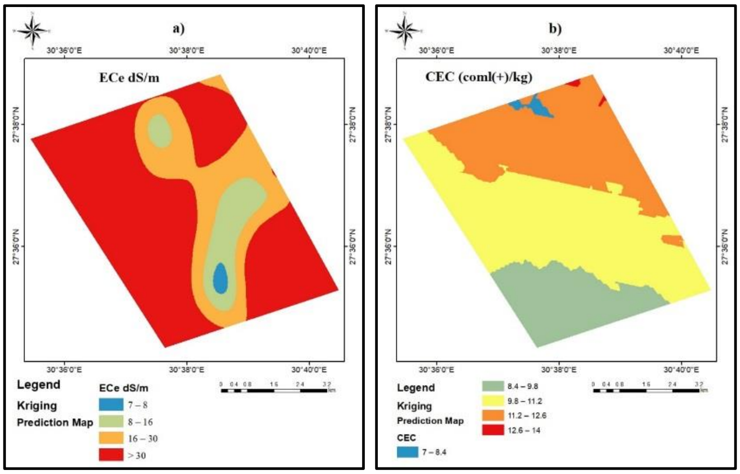

Figure (3): Spatial variability of a) the soil salinity (EC_e) and b) cation exchange capacity (CEC) of the study area.

3.2 Land capability

3.2.1 ASLE program

According to the applied system of land evaluation (ASLE) program, the obtained results showed that the study area has three classes of land capability, namely poor, very poor, and non-agricultural (Table 5 and Figure 4). Most of the investigated area are poor (C4). Soil profiles Nos. 1, 8, and 12 are very poor (C5), whereas soil profiles Nos. 3, 4, 9, and 10 are non-agricultural (C6).

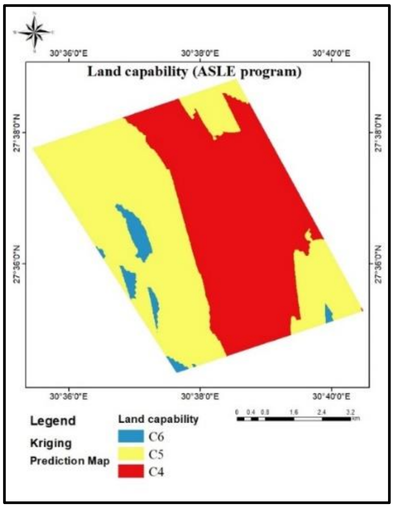

Figure (4): Land capability classes of the study area using the ASLE program.

Table (5): Land capability classes of the investigated soils using the applied system of land evaluation (ASLE) program.

Profile No.	The applied system of land evaluation (ASLE) program	
	%	Class
1	10.09	C5 (Very poor)
2	34.78	C4 (Poor)
3	9.64	C6 (Non-agricultural)
4	9.67	C6 (Non-agricultural)
5	31.22	C4 (Poor)
6	25.78	C4 (Poor)
7	32.65	C4 (Poor)
8	11.28	C5 (Very poor)
9	9.50	C6 (Non-agricultural)
10	6.83	C6 (Non-agricultural)
11	34.67	C4 (Poor)
12	12.69	C5 (Very poor)

3.2.2 MicroLEIS (Cervatana model)

Concerning the application of the microcomputer land evaluation information system (MicroLEIS-Cervatana model), all the study areas have a marginal capability grade, except soil profile No. 2 which has a moderate capability grade (Table 6 and Figure 5). The soil limitations are coarse soil texture, soil salinity, soil fertility, and erosion risk.

3.3 Land suitability

3.3.1 ASLE program

The land suitability classes for some selected crops using the applied system of land evaluation program that can be grown in the study area are shown in Table (7) and Figure (6).

Table (6): Land capability grades of the studied soils using MicroLEIS program (Cervatana model).

Profile No.	MicroLEIS program (Cervatana model)
	Grade
1	N1(Marginal)
2	S3r (Moderate)
3	N1(Marginal)
4	N1(Marginal)
5	N1(Marginal)
6	N1(Marginal)
7	N1(Marginal)
8	N1(Marginal)
9	N1(Marginal)
10	N1(Marginal)
11	N1(Marginal)
12	N1(Marginal)

r: Erosion risk, 1: Soil limitation.

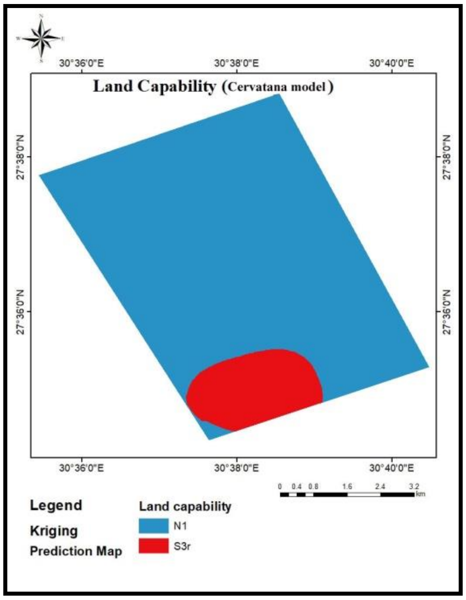

Figure (5): Land capability classes of the study area using MicroLEIS program (Cervatana model).

Accordingly, the soils of the study area have in general a widely range of suitability grades, from highly suitable (S1) to not suitable N (currently not suitable, N1 and permanently not suitable, N2). Most of the selected crops are highly suitable, suitable moderately suitable, and marginally suitable for field crops, forage crops, vegetables, and fruit crops, except crops rice, cabbage, and banana that are currently not suitable (N1) and permanently not suitable (N2) for some soils.

Table (7): Land suitability classes under the surface, sprinkler, and drip irrigation systems of the study area for selected crops using ASLE program.

Profile No.	Field Crops											Forage Crops		Vegetables							Fruit Crops							
	Sunflower	Faba bean	Barley	Sugar beet	Wheat	Cotton	Peanut	Maize	Soya bean	Sugarcane	Rice	Alfalfa	Sorghum	Tomato	Pepper	pea	Water melon	Onion	Potato	Cabbage	Date palm	Fig	Olive	Grape	Apple	Pear	Citrus	Banana
1	S_4	NS_1	NS_2	NS_2	NS_2	NS_1	NS_1	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	S_4	S_4	S_4	S_4	NS_2	NS_1	NS_2	S_4	S_4	S_4	S_4	NS_1	NS_2	NS_1	NS_2
2	S_2	S_3	S_4	S_4	S_4	S_2	S_2	S_3	S_3	S_4	NS_2	S_4	S_3	S_2	S_2	S_2	S_2	S_4	S_3	NS_1	S_2	S_2	S_2	S_2	S_3	S_4	S_2	NS_2
3	S_4	NS_1	NS_2	NS_2	NS_2	NS_1	NS_1	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	S_4	S_4	S_4	S_4	NS_2	NS_1	NS_2	S_4	S_4	S_4	S_4	NS_1	NS_2	NS_1	NS_2
4	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	NS_1	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	S_4	S_4	NS_1	NS_1	NS_2	NS_1	NS_2	S_4	NS_1	NS_1	NS_1	NS_1	NS_2	NS_1	NS_2
5	S_2	NS_1	S_4	S_4	S_4	S_3	NS_1	NS_1	NS_1	S_4	NS_2	S_4	S_3	S_2	S_4	NS_1	NS_1	NS_2	NS_1	NS_2	S_2	S_2	S_2	S_2	NS_1	NS_2	NS_1	NS_2
6	S_4	NS_2	S_4	S_4	NS_2	S_4	NS_1	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_1	NS_2	S_2	S_4	NS_2	S_4	NS_2	NS_2	NS_1	NS_2
7	S_2	NS_1	S_4	S_4	S_4	S_2	S_3	S_3	NS_1	S_4	NS_2	S_4	S_3	S_2	S_2	NS_1	S_3	S_4	S_3	NS_2	S_2	S_2	S_2	S_2	S_3	NS_1	S_3	NS_2
8	S_4	S_4	S_4	NS_2	NS_2	S_2	NS_1	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	S_4	S_4	S_4	S_4	NS_2	NS_1	NS_2	S_2	S_4	S_4	S_4	NS_1	NS_2	NS_1	NS_2
9	S_3	NS_1	S_4	S_4	NS_2	S_3	NS_1	NS_1	NS_1	NS_2	NS_2	NS_2	NS_1	S_4	S_4	NS_1	NS_1	NS_2	NS_1	NS_2	S_2	S_4	NS_1	S_4	NS_1	NS_2	NS_1	NS_2
10	S_4	NS_2	S_4	S_4	S_4	S_4	NS_1	NS_2	NS_2	NS_1	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_2	NS_1	NS_2	S_2	S_3	S_4	NS_1	NS_2	NS_2	NS_1	NS_2
11	S_1	S_1	S_1	S_1	S_1	S_2	S_2	S_2	S_2	S_2	NS_2	S_1	S_2	S_1	S_1	S_1	S_1	S_1	S_2	NS_2	S_1	S_1	S_1	S_1	S_2	S_2	S_1	NS_2
12	S_2	S_2	S_4	S_4	S_4	S_2	S_2	S_2	S_2	S_4	NS_2	S_4	S_2	S_2	S_2	S_2	S_2	S_3	S_2	NS_1	S_1	S_1	S_1	S_2	S_2	S_4	S_2	NS_2

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 %).

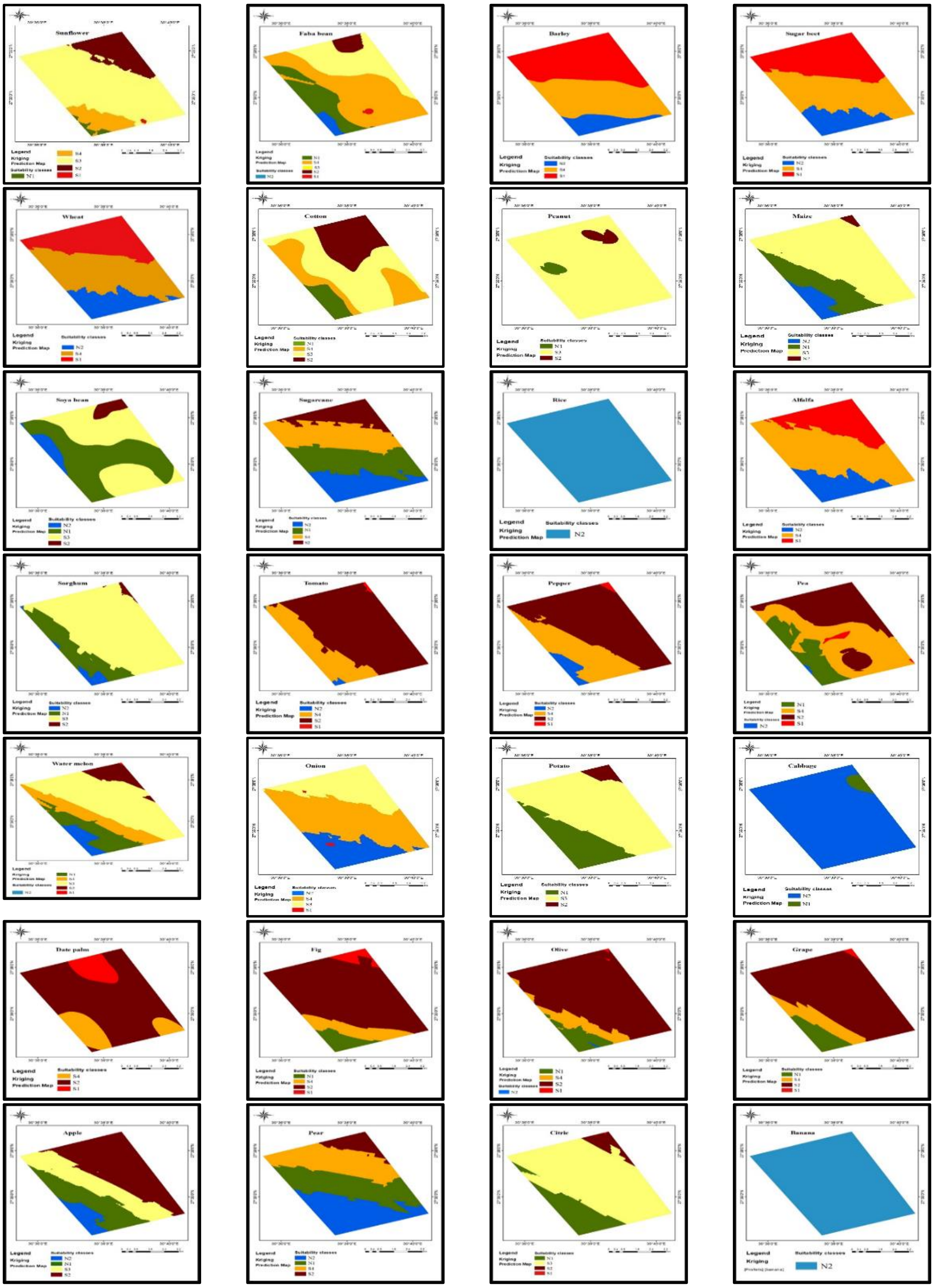

Figure (6): Land suitability of the study area for selected crops using ASLE program.

3.3.2 MicroLEIS (Almagra model)

In general, the soils of the study area are not suitable (5) for the selected crops using the microcomputer land evaluation information system (MicroLEIS-Almagra model) with few exceptional cases which are present and illustrated in Table (8) and Figure (7) respectively. The soil limitations of the current study are soil texture, soil salinity, and soil fertility.

3.4 Geostatistical analysis

Geostatistical analyses for mapping distribution of some soil properties, land capability, and land suitability rates were calculated using variance structure that was performed using eleven semi-variogram models; circular, spherical, tetraspherical, pentaspherical, exponential, gaussian, rational quadratic, hole effect, k-bessel, j-bessel and stable.

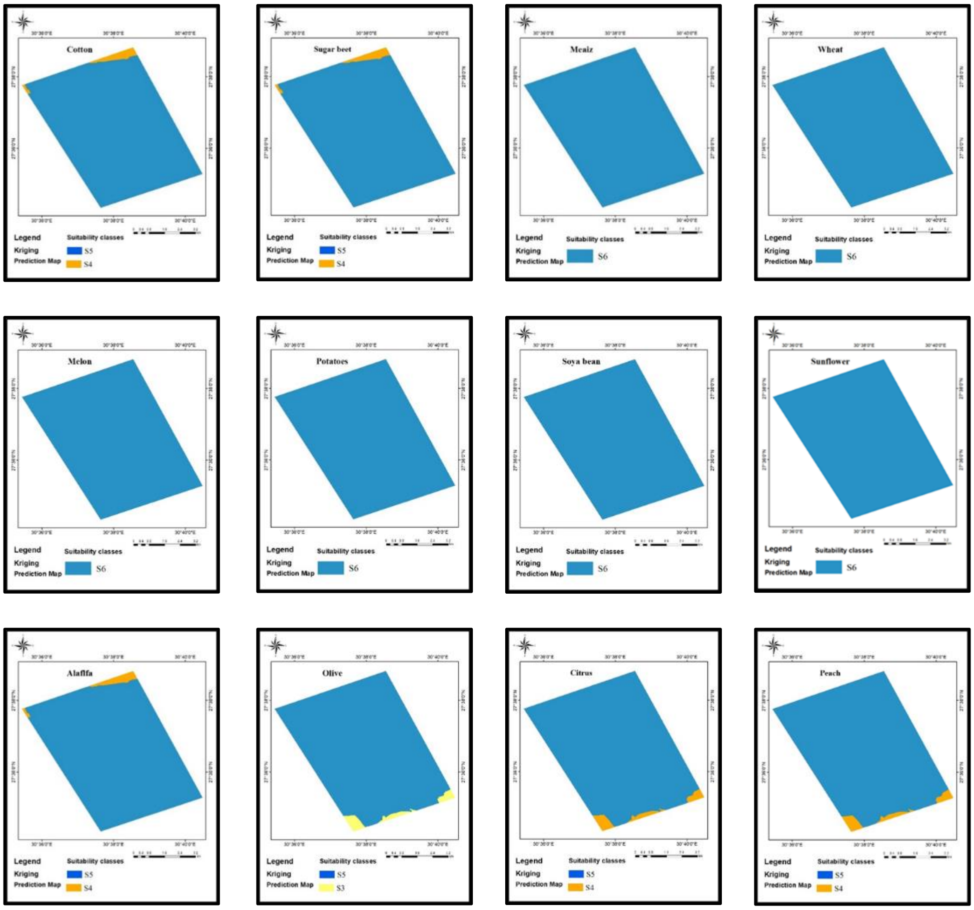

Figure (7): Land suitability of the study area for some selected crops using MicroLIES (Almagra model).

Table (8): Land suitability classes of the study area for some selected crops using the MicroLIES (Almagra model) program.

Profile No.	Annual crops								Semi-annual crops	Perennial crops		
	Cotton	Sugar-beet	Maize	Wheat	Melon	Potatoes	Soya- bean	Sunflower	Alfalfa	Olive	Citrus	Peach
1	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts	S_5ts
2	S_5t	S_5t	S_5t	S_5t	S_5t	S_5t	S_5t	S_5t	S_5t	S_3ts	S_4ts	S_4ts
3	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
4	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
5	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
6	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
7	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
8	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
9	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
10	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s
11	S_4ts	S_4ts	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_4ts	S_5s	S_5s	S_5s
12	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s	S_5s

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

Table (9): Geostatistical analyses of some soil parameters of the study area.

Method	Parameter	Model	Mean	Mean Standardized	Root Mean Square Standardized
Ordinary Kriging	Calcium carbonate	K-Bessel	-0.0633	-0.0083	1.1270
	Gypsum content	K-Bessel	-0.0216	-0.0192	2.0195
	Soil salinity	J-Bessel	0.9990	-0.1805	1.2543
	Cation exchange capacity	Circular	-0.1575	-0.0707	1.1288
	Land capability by ASLE	J-Bessel	1.9439	0.1601	1.2242
	Land capability by MicroLEIS	J-Bessel	0.8857	0.1823	1.9774
	Land suitability using ASLE	Stable	-0.3242	-0.0144	1.2039
	Land suitability using MicroLEIS	Stable	-0.0763	-0.0123	1.1958

However, the best four models for evaluation were circular, J-Bessel, K-Bessel, and stable depending on values of mean prediction errors, root means square prediction errors, and mean standardized prediction errors which should be close to 0 and root mean square standardized prediction errors which must close to 1 (Table 9).

4. Conclusion

In conclusion, the assessment results of land capability and land suitability for the selected crops helps in planning sustainable agriculture programs. Integration between geographic information systems (GIS), ASLE, and MicroLIES programs was undertaken in these soils to assess the land performance. The results of these soils indicated that the major soil limitations are soil texture, soil salinity, and low soil fertility characteristics, which can be improved using good management practices such as adding organic matter, fertilizers for upgrade the fertility, leaching the excess salt, and good agriculture practices for crops. These improvements will develop the potential suitability. Ultimately, from this study, it can be mentioned that the geostatistical approach and GIS are effective and strong tools for land capability and suitability studies and hence for sustainable planning of land use.

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