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Land capability assessment for agriculture at West Assiut, Western Desert, Egypt

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Abstract

The objective of this research is to assess the land capability of some soils located at the western portion of Manfalut district, Assuit governorate, Egypt. This study showed that most of the soil profiles of these soils reveal that no clear pattern of gravel content distribution can be noticed with depth. The texture grade of the examined soil samples is mainly sand, loamy sand, sandy loam, loam, silt loam and sand clay loam. Organic matter (OM) content ranges between low (0.03%) to high (1.70%). Concerning total calcium carbonate ($CaCO_3$) content, most of these soil samples are moderately calcareous and strongly calcareous. Furthermore, almost all soil samples have slighty gypsiric (less than 5%). Regarding soil reaction (pH), most of the investigated soil samples are slightly alkaline (7.4 to 7.8 pH). The EC_e values of these soil profiles vary between 0.52 and 185.20 dS/m indicated that the studied soils are non-saline to strongly saline. While the cation exchange capacity (CEC) values differ from 2.37 to 15.52 $cmol_c$/kg. Meanwhile the exchangeable sodium percentage (ESP) values range between 0.54 and 23.80%. The soils of the investigated area have been evaluated using the land capability systems. These systems are based on the following parameters such as slope, topography, depth, texture, calcium carbonate content, gypsum content, salinity and alkalinity, cation exchangeable capacity, exchangeable sodium percentage and sodium adsorption ratio. Based on the actual soil properties, land capability for agricultural production was assessed using the ALES and Micro-LEIS systems. These results indicate that the land capability of the study area using automated land evaluation systems (ALES) varies from moderate to unsuitable due to different limiting factors such as soil depth, drainage, soil salinity and soil alkalinity. Whilst the land capability of these soils using MicroLEIS- Cervatana model differs between good class (S2) and Marginal class (N). The findings show that the region currently insufficiency high capability and land capability for most systems which have been used vary from moderate or marginally suitability classes to non-suitable.

Keywords: West Assiut, Automated Land Evaluation Systems program, MicroLEIS- Cervatana model program.

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1. Introduction

One of the major current aims of the Egyptian policy is to increase agricultural production by increasing either the productivity or the area of arable land to cope with the ever-increasing demands of the ever-growing population that increases at an alarming rate. To increase the area of arable land, the western desert represents an important source for such an objective. The western desert of Egypt is considered to be the main source of Egyptian agricultural development, and there will be national agricultural projects in the coming period in accordance with the updated 2030 agricultural strategy. Horizontally extending agriculture has always been considered an essential element in Egypt's development strategy. Thus, over the past few decades, Egyptian agricultural policy has focused on expanding the area of arable land by clearing new desert land. The process of evaluating land involves interpreting the characteristics of the soil, crop cover, climate, and other data layers linked to the particular land-use in order to identify and determine the best land-use option among these alternatives (Sayed, 2006). The land Master Plan will provide the necessary information to select the best lands to accomplish this strategy. The purpose of land capability is to research and record all data to select the most appropriate and intensive agricultural use of the land without undue risk of land degradation (Yousif, 2018). According to Moghanm (2014), land capability classification could be a system of grouping soils, totally on the premise of their capability to form common cultivated crops while not deteriorating over an extended amount of time. The standard of land evaluation systems is based on the factors input and economic output. presently applied of land evaluation systems belong to four main groups: categoric systems (or capability system), parametric systems, special purpose systems and crop-specific assessments (Sayed, 2013). The program of the Microcomputer Land Evaluation Information System (MicroLIES) package, which has evolved significantly towards a user-friendly agro-ecological system for sustainable land management, was prepared by De la Rosa *et al*. (2004; 2009). The MicroLIES program operates in an interactive manner by comparing the properties of the land unit values with the generalization levels assigned for each use capability class. The findings of a qualitative evaluation process or overall interpretation of the following biophysical parameters, such as relief, soil, climate, and current use or vegetation, lead to the prediction of the general land use capability (Cervatana model).On the other hand, the Automated Land Evaluation System (ALES) is a computer program that allows land evaluators to build expert systems that can evaluate land according to the method presented in the Food and Agriculture Organization’s publication "Framework for Land Evaluation" (Rossiter and Wambeke, 1997). Decision makers can build their own expert system with ALES, taking into account local conditions and objectives. El-Sayed *et al*. (2020) studied the soils of Wadi Tag El-Wabar, West of Sohag area and they found that these soils are good (G2), Fair (G3), poor (G4) and non-agricultural (G5) that represents 4.13, 30.07, 34.92 and 30.88%, respectively, of total area for the agricultural use by applying modified storie index rating (O'Geen *et al*., 2008). Using the MicroLIES Cervatana model, Fadel and Sayed (2020) assessed the soils of the El-Qusiya area in Assiut, Egypt, one of the recently reclaimed sites. Their output data indicated that this region's land capability classes were good (S2), moderate (S3), and marginal (N), with limiting factors of soil (i), erosion risks (r), and bioclimatic deficit (b). Sayed (2013) evaluated the land capability classes of El-Hammam Canal using ALES program and he found that this area was marginal capability (S3) to not suitable (S5) due to different limiting factors such as $CaCO_3$ (c), texture (t) and soil depth (s). According to Sayed and Khalafallah (2021), the findings of land capability evaluation indicated that the soils of Dashlut, Assuit region were poor (C4), very poor (C5) and non-agricultural (C6) using the ASLE program. Whereas the MicroLEIS (Cervatana model) program demonstrated that theses soils had moderately (S3) and marginally (N1) capable grades. The aim of this study to assess land capability using ALES and MicroLIES (Cervatana model) programs to qualify soil properties for irrigated land use.

2. Materials and methods

2.1 2.1. Study area

The area under investigation at the western portion of Manfalut district, Assuit governorate, Egypt represents a new reclaimed and promised site for agriculture. It lies between longitudes 30°50′10″ and 30°57′55″E and latitudes 27°13′41″ and 27°18′27.5″N (Figure 1). The total study area is about 76 km^2 representing nearly 18780.36 feddans (7600 hectares). The climate condition of this area was a thermic temperature regime and an aridic soil moisture regime where the mean annual temperature, rainfall, evaporation and wind velocity are 22.12 °C, 0.44 mm, 13.71 mm/day and 6.4 m/s respectively.

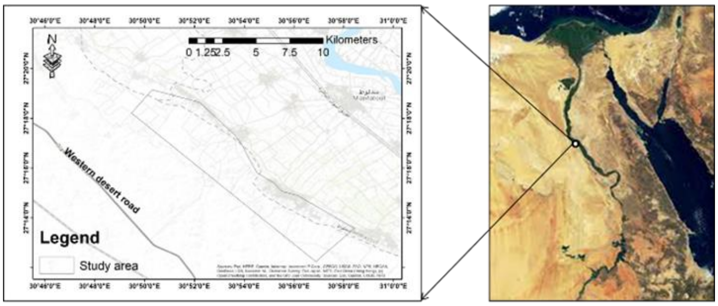

Figure (1): The location map of the study area.

2.2 Geological formations

Geologically, the study area is essentially occupied by sediments belonging to the Quaternary and Tertiary formations (Figure 2). Quaternary sediments represented in sand dunes, Nile deposits, and others (*i.e.*, fanglomerate) while Tertiary formations were mainly Eocene (*i.e.*, thick marine limestone with chert and minor clay beds) (Geological Survey of Egypt, 1981; Omer, 1996; Osman 1980; Said, 1962; 1981).

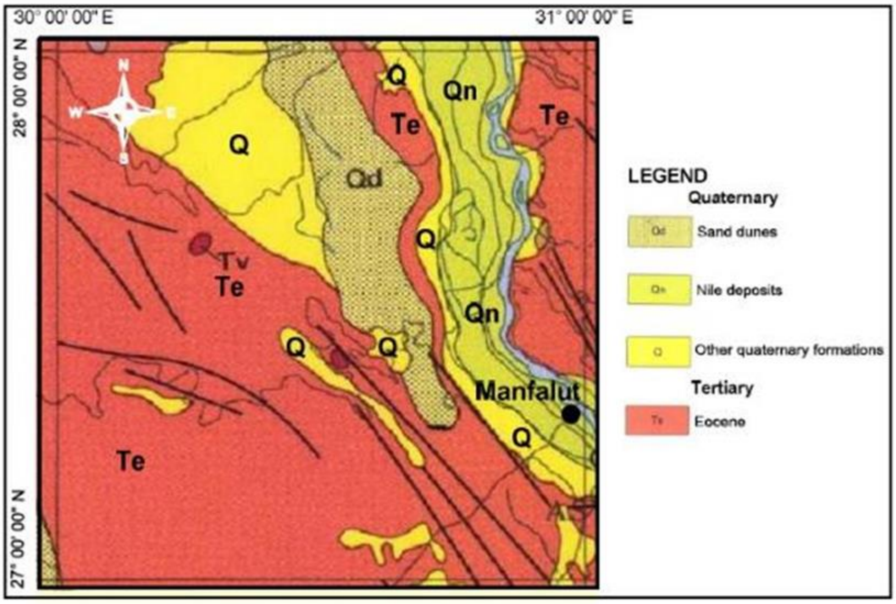

Figure (2): Geological map of the study area (modified after Geological Survey of Egypt, 1981).

2.3 Geomorphological Features

The area under consideration forms a long stripe parallel to the western desert road at Manfalout area. The geomorphological features of west Manfalut (Figure 3) were classified into three main geomorphological units, that have unique shape, pattern and relief, which described by Said (1981) and Abou El-Anwar *et al.* (2019) and it can be summarized as follows: (1) old alluvial plain (sand and gravel), (2) young alluvial plain (silty clay cultivated lands), and (3) calcareous structural plateau (Eocene limestone covered by drift sands, flints, and boulders of carbonate). However, the study soils located within the first unite only.

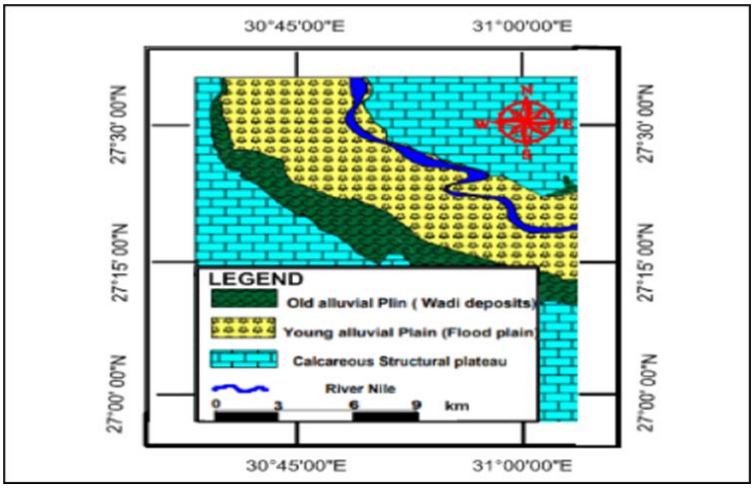

Figure (3): Geomorphological map of west Manfalut, Assuit, Egypt (modified after Abou El-Anwar *et al*., 2019).

2.4 Field studies

Thirty-two soil profiles were selected to evaluate the land capability of the study area as shown in Figure (4) based on ground elevations (50-130 m a.s.l) of the region under consideration (Figure 5). The locations of these soil profiles were recorded in the field using the Global Positioning System "Garmin GPS". These profiles were dug down to the suitable depth according to the nature of the soil material. All soil profiles were morphologically described according to the standard procedure and terminology as reported by FAO (2006) and Schoenberger *et al*. (2012). One hundred and sixteen representative soil samples were collected from different layers of all investigated soil profiles according to the pedomorphic variations.

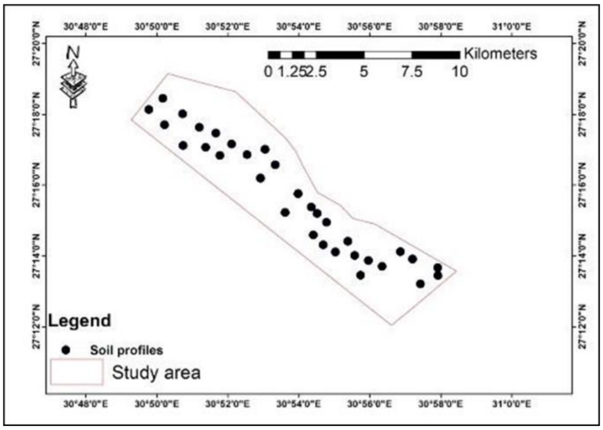

Figure (4): A soil profiles location map of the studied area.

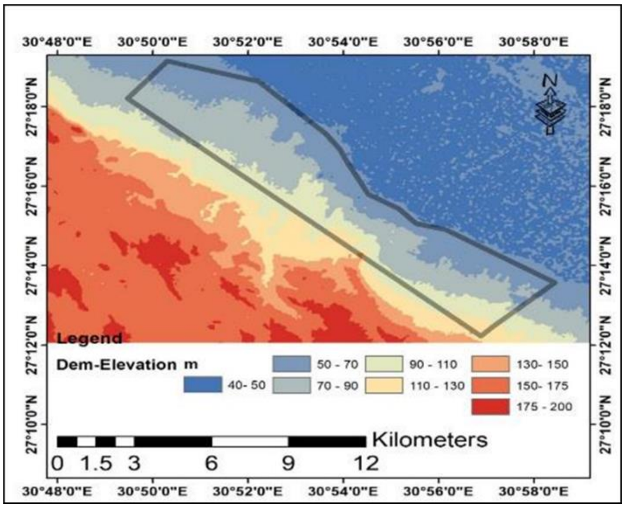

Figure (5): Digital elevation model of the study area.

2.5 Analytical methods

The collected soil samples were air-dried, crushed, sieved to pass through 2 mm sieve and stored in plastic containers for different analysis. The physico-chemical properties of the investigated soil samples were determined at Faculty of agriculture laboratories, Al-Azhar University, Assuit. In these samples the gravel content was measured by volume according to Schoenberger *et al*. (2012). While the particle-size distribution of the soil samples was performed using the pipette method that was described by Gavlak *et al*. (2005). However, the organic matter content of the soil samples was determined using the dichromate oxidation method as described by Walkely and Black method (Bashour and Sayegh, 2007). Whilst the total calcium carbonate ($CaCO_3$) was determined using Scheibler's calcimeter (Nelson, 1982). Furthermore, the Soil reaction (pH) was measured in 1:2.5 of soil to water suspension at 25 °C using a glass electrode as reported by Alvarenga *et al*. (2012). Moreover, the soil salinity was determined as electrical conductivity of soil paste extract (EC_e) using Beckman Conductivity Bridage at 25 °C according to Bashour and Sayegh (2007). The cation exchange capacity (CEC) was measured according to Bashour and Sayegh (2007). While the exchangeable sodium percentage (ESP) was calculated using the values of CEC and exchangeable sodium by the following equation:

$$ESP = \frac{Na^{+}\ (\text{cmol}_c\ /kg)}{CEC\ (cmol_c\ /kg)} \times 100$$

2.6 Land capability evaluation

2.6.1 Automated Land Evaluation System

In the study area automated land evaluation system (ALES) model was applied to assess land capability of these soils. It depends on soil characteristics (slope, effective depth, drainage, texture class, cation exchangeable capacity, exchangeable sodium percentage, calcium carbonate content and soil salinity). The soil characteristics rates that used in the capability model are given in Table (1). In light of soil characteristics, the classes of lands can be distinguished according to this model as shown in Table (2).

Table (1): Soil characteristics which used in the capability model of the study area.

Soil characteristics	Class 1 High Capability	Class 2 Moderately Capability	Class 3 Marginal Capability	Class 4 Limited Capability	Class 5 Not Suitable
Slope %	<2	2-5.	5-8.	8-16.	>16
Effective depth (cm)	≥ 120	90-120	60-90	25-60	<25
Drainage [(1)]	good	moderate	imperfect	Poor but drainable	Poor but not drainable
Texture class [(2)]	L, SL, SCL, CL, SC	SiL, SiCL,SiC, Si, light C	F. S, C	S, G.S	Extremely G.sand
CEC (cmolc/kg)	≥ 30	15-30	10-15.	5-10.	<5
ESP	<15	15-20	20-30	30-40	>40
$CaCO_3$ %	<10	10-20.	20-40	40-50	>50
EC (dSm^{-1})	<4	4-8.	8-16.	16-32	>32

[(1)] According to (Shalaby *et al*., 2006). [(2)] Texture classes: L: Loamy, SL: Sandy loam, SCL: Sandy clay loam, CL: Clay loam, SC: Sandy clay, SiL: Silty loam, SiCL: Silty clay loam, SiC: Silty clay, Si: Silty, F.S.: Fine sand, C: Clay, S: Sandy, G.S.: Gravely sand.

Table (2): Land capability classes and soil grades using ALES program.

Land Capability class	Grade
C1	Highly Capability
C2	Moderately Capability
C3	Marginal Capability
C4	Limited Capability
C5	Not Suitable

2.6.2 MicroLEIS (Cervatana model)

MicroLEIS (Cervatana model) Internet-based program (De la Rosa *et al*., 2004) was also applied for evaluation land capability of the soils of the investigated area. This program includes land capability orders, classes, subclasses and limitation factors as present in Table (3).

Table (3): Land capability orders, classes, subclasses and limitation factors of MicroLEIS program (CERVATANA model).

<table>
<tr><th colspan="3">Land capability orders and classes</th><th colspan="2">Land capability subclasses</th><th>Limitation factors</th></tr>
<tr><td rowspan="3">S</td><td>S1</td><td>Excellent</td><td>Slope</td><td>t</td><td>Slope</td></tr>
<tr><td>S2</td><td>Good</td><td rowspan="5">Soil</td><td rowspan="5">l</td><td>Useful depth</td></tr>
<tr><td>S3</td><td>Moderate</td><td>Texture class</td></tr>
<tr><td rowspan="7">N</td><td colspan="2" rowspan="7">Marginal or Nil</td><td>Stoniness and rockiness</td></tr>
<tr><td>Drainage class</td></tr>
<tr><td>Salinity</td></tr>
<tr><td rowspan="3">Erosion risks</td><td rowspan="3">r</td><td>Soil erodibility</td></tr>
<tr><td>Slope gradient</td></tr>
<tr><td>Vegetation density</td></tr>
<tr><td>Bioclimatic deficit</td><td>b</td><td>Aridity degree</td></tr>
</table>

3. Results and Discussion

3.1 Soil characteristics of the study area

The analytical data and weighted mean of the investigated soil profiles are shown in Table (4a,b). The gravel content of the studied soil samples varies between 0.81 to 64.02% by volume with an average value of 17.34% and with profiles weighted mean ranges from 3.03% and 56.10%. Most of the soil profiles of these soils reveal that no clear pattern of gravel content distribution can be noticed with depth. The sand fraction percentage varies from 40.22 to 98.24% with an average value of 76.08% and with profiles weighted mean differs between 46.61 and 92.42%.

Table (4a): Some physico-chemical characteristics of the study area.

Profile No	Depth of layer (cm)	Gravel by volume (%)	Particle-size distribution				OM	$CaCO_3$	Gypsum	pH	EC_e	CEC	ESP
			Sand %	Silt %	Clay %	Texture grade	%	%	%	(1:2.5)	dSm^{-1}	$cmol_c/kg$	
1	0 – 15	12.02	48.80	45.60	5.60	Sandy loam	0.76	14.10	0.10	7.56	1.80	10.98	10.77
	15 – 45	9.21	80.60	13.00	6.40	Sand	0.27	6.90	0.00	8.04	0.52	4.89	11.84
	45 – 75	2.80	89.60	7.20	3.20	Sand	0.06	8.10	0.00	8.13	0.63	3.91	9.56
	75 – 150	1.75	82.77	12.68	4.55	Loamy sand	0.27	9.30	0.00	8.31	0.62	5.39	10.62
Weighted mean		4.48	80.31	14.94	4.76	Loamy sand	0.28	9.06	0.01	8.13	0.70	5.40	10.67
2	0-15	18.36	50.21	38.17	11.62	Gravelly loam	0.15	3.30	1.29	7.54	18.47	9.74	18.69
	15-20	26.30	45.00	40.16	14.84	Gravelly loam	0.15	5.10	1.63	7.50	22.70	10.61	19.70
	20-30	27.03	49.18	38.13	12.69	Gravelly loam	0.03	6.60	1.73	7.45	27.80	11.65	20.08
	30-85	40.00	43.22	50.66	6.12	Very gravelly silt loam	0.03	9.60	1.78	7.50	25.90	8.87	20.85
	85-100	21.05	74.18	17.06	8.76	Gravelly sandy loam	0.03	1.50	1.15	7.40	16.27	12.59	19.97
	100-150	61.50	67.20	27.20	5.60	Extremely gravelly sandy loam	0.09	2.10	1.49	7.39	20.50	12.17	19.71
Weighted mean		41.79	55.47	37.05	7.49	Very gravelly sandy loam	0.07	5.31	1.56	7.45	22.41	10.77	20.08
3	0-20	20.55	87.20	8.27	4.53	Gravelly loamy sand	0.18	9.60	0.89	7.45	19.77	5.81	20.13
	20-60	49.38	84.14	7.80	8.06	Very gravelly loamy sand	0.24	9.30	1.17	7.35	76.60	6.58	22.93
	60-150	39.16	77.32	15.33	7.35	Very gravelly loamy sand	0.21	6.60	1.22	7.26	55.90	10.87	22.58
Weighted mean		39.40	80.46	12.38	7.16	Very gravelly loamy sand	0.21	7.72	1.16	7.31	56.60	9.27	22.35
4	0-10	9.21	91.24	5.50	3.26	Sand	0.15	3.60	0.68	7.64	5.74	3.45	16.39
	10-.20	8.98	88.01	5.59	6.40	Loamy sand	0.12	5.10	0.54	7.63	7.24	4.25	15.96
	20-40	15.14	93.16	4.50	2.34	Gravelly sand	0.15	5.10	0.19	8.10	3.68	3.48	15.52
	40-65	3.82	93.60	3.20	3.20	Sand	0.15	3.90	0.50	8.20	9.79	5.52	19.90
	65-95	15.48	86.14	7.73	6.13	Gravelly loamy sand	0.12	2.40	0.74	7.76	10.85	4.92	20.48
	95-150	7.53	76.80	14.40	8.80	Sandy loam	0.15	3.90	0.68	7.68	11.12	5.03	19.77
Weighted mean		9.73	85.36	8.70	5.94	Loamy sand	0.14	3.82	0.59	7.83	9.24	4.70	18.89
5	0-15	14.08	65.16	28.14	6.70	Sandy loam	1.09	7.20	0.40	7.56	8.29	10.74	15.25
	15-35	11.18	89.44	7.44	3.12	Gravelly sand	0.15	4.50	0.03	7.64	2.15	5.26	7.64
	35-150	19.85	70.21	21.35	8.44	Gravelly sandy loam	0.21	8.10	1.05	7.48	35.90	6.85	22.38
Weighted mean		18.12	72.27	20.17	7.56	Gravelly sandy loam	0.29	7.53	0.85	7.51	28.64	7.13	19.70
6	0-15	46.92	84.61	10.89	4.50	Very gravelly loamy sand	0.24	17.40	0.82	7.42	29.90	12.35	22.53
	15-55	34.22	78.32	15.45	6.23	Gravelly loamy sand	0.21	10.50	0.76	7.41	53.30	9.37	22.61
	55-80	37.02	75.12	17.68	7.20	Very gravelly sandy loam	0.15	5.10	0.99	7.56	19.50	10.50	19.05
	80-130	9.75	40.22	50.66	9.12	Silt loam	0.15	7.50	2.10	7.58	67.70	13.48	23.53
	130-150	32.06	62.13	15.95	21.92	Gravelly sand clay loam	1.39	4.50	3.33	7.73	36.50	14.26	23.41
Weighted mean		27.51	63.56	27.17	9.27	Gravelly sandy loam	0.34	8.49	1.59	7.54	47.89	11.47	22.42
7	0-20	18.74	89.25	5.61	5.14	Gravelly sand	1.70	2.10	0.00	7.69	3.36	14.78	17.18
	20-35	21.17	84.62	8.47	6.91	Gravelly loamy sand	0.06	8.40	0.02	8.06	1.87	11.43	17.21
	35-150	6.89	91.20	4.69	4.11	Sand	0.09	6.30	0.00	8.38	0.99	5.68	16.72
Weighted mean		9.90	90.28	5.19	4.53	Sand	0.30	5.95	0.00	8.26	1.39	7.70	16.83
8	0-40	39.69	85.51	7.57	6.92	Very gravelly loamy sand	0.42	13.80	1.14	7.42	151.10	9.53	23.58
	40-60	45.60	66.88	25.12	8.00	Very gravelly sandy loam	0.42	40.50	1.52	7.35	161.50	11.59	23.52
	60-100	51.08	51.20	44.00	4.80	Very gravelly sandy loam	0.15	67.00	0.99	7.39	56.10	13.48	22.89
	100-150	37.12	50.22	37.52	12.26	Very gravelly Loam	0.21	45.30	1.15	7.26	66.60	7.22	22.19
Weighted mean		42.66	62.11	29.61	8.28	Very gravelly sandy loam	0.28	42.05	1.15	7.35	98.99	10.07	22.92
9	0-10	8.04	74.23	18.65	7.12	Sandy loam	0.18	9.00	1.28	7.63	32.30	6.65	22.75
	.10-30	7.60	87.43	7.15	5.42	Loamy sand	0.15	7.80	0.23	7.80	27.70	6.66	23.13
	30-70	5.75	90.17	5.53	4.30	Sand	0.18	5.40	0.66	7.46	40.90	8.55	22.33
	70-150	38.85	78.53	14.10	7.37	Very gravelly loamy sand	0.27	6.30	0.62	7.27	32.80	3.65	20.71
Weighted mean		23.80	82.53	11.19	6.27	Gravelly loamy sand	0.22	6.44	0.62	7.42	34.25	5.93	21.60
10	0-10	13.74	48.20	39.13	12.67	loam	1.18	12.00	0.92	7.43	7.16	3.62	16.74
	.10-35	18.07	80.14	12.66	7.20	Gravelly loamy sand	0.45	9.60	0.24	7.72	3.09	3.53	16.78
	35-150	8.97	74.44	19.15	6.41	Gravelly sandy loam	0.24	6.00	0.09	7.78	1.83	3.32	14.38
Weighted mean		10.80	73.64	19.40	6.96	Sandy loam	0.34	7.00	0.17	7.75	2.40	3.23	14.94
11	0-20	7.60	69.60	22.19	8.21	Sandy loam	0.15	4.50	0.80	7.77	7.52	14.09	20.89
	20-55	35.49	47.18	39.13	13.69	Very gravelly Loam	0.06	11.70	1.34	8.07	11.78	11.57	21.24
	55-130	19.35	40.22	48.22	11.56	Gravelly silt loam	0.12	9.60	1.52	7.69	31.40	4.27	22.36
Weighted mean		21.89	46.61	41.77	11.62	Gravelly loam	0.11	9.38	1.36	7.80	19.45	7.69	21.83
12	0-15	0.81	72.13	18.96	8.91	Sandy loam	0.03	6.30	0.42	7.65	3.21	2.90	10.83
	15-95	27.01	92.86	3.09	4.05	Gravelly Loamy sand	0.30	39.60	0.35	7.37	5.54	5.17	8.03
	95-115	28.51	98.24	0.33	1.43	Gravelly sand	0.03	6.60	0.38	7.57	3.96	11.48	9.54
	115-150	0.96	96.80	1.03	2.17	Sand	0.61	7.80	0.08	8.07	1.30	3.53	8.89
Weighted mean		18.51	92.42	3.83	3.75	Gravelly sand	0.31	24.45	0.30	7.59	4.74	5.37	8.71
13	0-30	11.53	91.60	3.70	4.70	Sand	0.06	7.50	1.04	7.50	28.80	7.30	12.90
	30-85	48.58	80.43	12.37	7.20	Very gravelly loamy sand	0.21	3.90	0.72	7.48	3.15	3.83	6.29
	85-150	5.08	89.16	5.24	5.60	Sand	1.54	4.50	0.55	7.43	2.85	3.77	3.09
Weighted mean		22.32	86.45	7.55	6.01	Gravelly loamy sand	0.76	4.88	0.71	7.46	8.15	4.60	6.22
14	0-25	17.99	73.86	18.85	7.29	Gravelly sandy loam	0.39	24.00	0.32	6.78	185.20	11.89	23.34
	25-70	12.67	59.14	32.22	8.64	Sandy loam	0.79	30.60	0.92	7.17	27.20	5.83	17.78
	70-150	18.34	57.54	33.94	8.52	Gravelly sandy loam	0.91	33.60	1.21	7.36	7.79	6.46	19.44
Weighted mean		16.58	60.74	30.91	8.35	Gravelly sandy loam	0.79	31.10	0.97	7.21	43.18	7.00	19.59

Table (4b): Some physico-chemical characteristics of the study area.

Profile No	Depth of layer (cm)	Gravel by volume (%)	Particle-size distribution				OM %	$CaCO_3$ %	Gypsum %	pH (1:2.5)	EC_e dSm^{-1}	CEC $cmol_c/kg$	ESP
			Sand %	Silt %	Clay %	Texture grade							
15	0-20	7.58	40.22	50.66	9.12	Silt loam	0.06	9.90	1.17	7.60	4.55	11.91	12.86
	20-40	19.72	80.30	13.68	6.02	Gravelly loamy sand	0.09	8.70	0.00	8.28	2.09	6.68	19.65
	40-150	10.32	82.06	10.76	7.18	Loamy sand	0.09	8.10	0.54	8.63	1.19	6.60	19.18
Weighted mean		11.21	76.25	16.47	7.28	Sandy loam	0.09	8.42	0.55	8.45	1.76	7.67	18.40
16	0-15	5.09	56.12	22.64	21.24	Sand clay loam	1.18	6.90	1.26	7.53	6.30	14.43	23.07
	15-55	8.87	41.20	48.64	10.16	Loam	0.06	6.60	1.24	7.32	4.03	4.94	12.22
	55-150	4.19	80.23	12.15	7.62	Loamy sand	0.12	6.90	0.96	7.40	7.60	5.90	18.87
Weighted mean		5.53	67.41	22.93	9.66	Sandy loam	0.21	6.82	1.06	7.39	6.52	6.53	17.52
17	0-15	13.14	83.09	9.45	7.46	Loamy sand	1.51	7.80	1.23	7.45	48.50	9.42	21.58
	15-35	5.95	79.96	13.16	6.88	Loamy sand	0.12	6.30	0.38	7.56	4.27	5.00	15.09
	35-70	3.37	85.24	8.58	6.18	Loamy sand	0.06	6.30	0.17	7.67	2.08	2.71	16.14
	70-150	9.95	56.83	35.00	8.17	Sandy loam	0.12	6.60	0.05	8.00	1.28	3.34	11.53
Weighted mean		8.00	68.50	22.93	8.23	Sandy loam	0.24	6.40	0.23	7.56	6.44	3.70	13.58
18	0-15	8.41	55.02	35.16	9.82	Sandy loam	1.36	9.30	0.96	6.98	54.50	8.30	20.56
	15-150	2.51	86.32	7.56	6.12	Loamy sand	0.12	8.10	0.81	7.72	16.14	4.43	20.85
Weighted mean		3.10	83.19	10.32	6.49	Loamy sand	0.24	8.22	0.83	7.65	19.98	4.40	20.82
19	0-20	13.42	78.15	13.69	8.16	Sandy loam	0.64	7.80	0.42	7.25	5.91	11.44	14.38
	20-60	2.20	74.86	16.71	8.43	Sandy loam	0.15	3.30	0.30	7.64	1.32	2.37	20.75
	60-150	14.16	84.06	9.51	6.43	Loamy sand	0.12	5.10	0.53	7.66	2.38	2.80	6.45
Weighted mean		10.87	80.82	11.99	7.19	Loamy sand	0.20	4.98	0.45	7.60	2.57	3.80	11.32
20	0-15	11.86	55.45	37.29	7.26	Sandy loam	0.18	10.80	1.24	7.28	9.28	3.37	15.42
	15-35	25.89	72.13	18.96	8.91	Gravelly sandy loam	0.06	10.50	0.55	7.72	2.48	8.69	10.01
	35-150	1.31	74.18	19.77	6.05	Sandy loam	1.70	6.00	0.07	7.85	1.04	2.61	16.27
Weighted mean		5.64	72.03	21.41	6.55	Sandy loam	1.33	7.08	0.25	7.78	2.06	3.80	15.35
21	0-20	4.62	87.12	6.98	5.90	Loamy sand	0.15	10.50	0.98	7.82	24.30	8.48	22.76
	20-25	4.44	83.45	10.38	6.17	Loamy sand	0.15	10.50	0.87	7.62	27.70	15.36	23.15
	25-45	1.07	60.60	29.98	9.42	Sandy loam	0.06	3.60	0.81	7.47	34.40	11.22	23.12
	45-80	2.60	82.85	9.06	8.09	Sandy loam	0.15	4.50	0.83	7.50	9.24	12.29	15.17
	80-150	3.26	63.14	22.76	14.10	Sandy loam	0.09	3.60	1.19	7.44	4.18	2.77	9.32
Weighted mean		3.03	71.27	18.01	10.72	Sandy loam	0.11	4.96	1.02	7.51	12.86	7.23	14.78
22	0-30	22.79	55.99	26.05	17.96	Gravelly sandy loam	1.42	4.80	0.44	7.45	4.36	14.09	12.10
	30-50	14.28	57.14	30.22	12.64	Gravelly sandy loam	0.36	4.80	0.65	7.50	5.64	11.07	11.28
	50-75	8.28	64.22	24.12	11.66	Sandy loam	0.18	8.10	1.06	8.03	17.62	7.98	18.25
	75-150	1.02	78.12	13.66	8.22	Sandy loam	0.03	0.60	0.08	8.24	1.13	8.05	14.85
Weighted mean		8.35	68.58	20.09	11.33	Sandy loam	0.38	3.25	0.39	7.95	5.12	9.60	14.39
23	0-20	29.92	72.01	17.89	10.10	Gravelly sandy loam	0.33	10.80	0.87	7.30	17.45	11.03	17.78
	20-70	53.90	85.20	8.17	6.63	Very gravelly loamy sand	0.03	13.20	0.69	7.40	7.81	10.32	13.10
	70-150	64.02	83.52	9.28	7.20	Extremely gravelly loamy sand	0.18	18.60	0.58	7.26	25.30	13.72	22.08
Weighted mean		56.10	82.55	10.06	7.40	Very gravelly loamy sand	0.15	15.76	0.66	7.31	18.42	12.27	18.51
24	0-20	19.70	64.14	23.16	12.70	Gravelly sandy loam	0.85	7.50	0.28	7.83	3.58	13.57	16.21
	20-35	8.48	86.42	7.28	6.30	Loamy sand	0.06	10.50	0.73	7.43	5.59	12.84	14.54
	35-80	3.58	82.88	10.72	6.40	Loamy sand	0.03	5.40	0.54	7.40	3.57	7.63	8.93
	80-150	25.98	48.60	39.34	12.06	Gravelly loam	0.03	6.60	0.75	7.32	3.32	6.27	11.36
Weighted mean		16.67	64.74	25.39	9.87	Gravelly sandy loam	0.14	6.75	0.62	7.42	3.66	8.37	11.59
25	0-20	30.90	78.60	12.24	9.16	Gravelly sandy loam	1.33	9.00	0.75	7.01	1.54	13.25	0.54
	20-50	34.95	86.56	8.43	5.01	Gravelly loamy sand	0.30	10.50	0.72	7.33	10.50	11.66	12.42
	50-150	56.59	84.89	9.87	5.24	Very gravelly loamy sand	0.15	18.60	0.78	7.35	7.15	9.68	10.25
Weighted mean		48.84	84.39	9.90	5.72	Very gravelly loamy sand	0.34	15.70	0.76	7.30	7.07	10.80	9.39
26	0-30	12.74	85.22	9.49	5.29	Loamy sand	0.42	16.50	0.94	7.07	37.00	10.37	22.02
	30-50	11.99	92.20	4.40	3.40	Sand	0.15	15.30	0.70	7.26	8.13	8.67	12.51
	50-75	7.24	93.60	5.60	0.80	Sand	0.15	21.90	0.58	7.35	3.98	9.23	10.91
Weighted mean		10.71	89.87	6.84	3.29	Sand	0.26	17.98	0.38	7.21	18.29	9.40	15.78
27	0-30	10.82	96.14	2.77	1.09	Sand	0.03	13.80	0.77	7.42	4.04	9.44	11.01
	30-50	13.12	86.20	7.40	6.40	Loamy sand	0.27	12.30	0.81	7.47	13.24	9.86	18.63
	50-75	10.09	92.34	3.93	3.73	Sand	0.15	10.80	0.45	7.56	9.96	6.77	19.81
	75-80	7.77	87.42	7.56	5.02	Loamy sand	0.09	10.20	0.73	7.61	8.19	9.06	18.27
	80-150	14.99	91.80	3.70	4.50	Gravelly sand	0.64	9.30	0.74	7.56	10.20	9.70	16.30
Weighted mean		12.85	91.87	4.17	3.96	Sand	0.37	10.88	0.71	7.52	9.27	9.27	16.20
28	0-15	9.85	95.20	3.91	0.89	Sand	0.18	8.10	0.29	7.33	4.24	13.25	23.29
	15-35	5.73	84.15	8.75	7.10	Loamy sand	0.15	10.50	0.75	8.29	6.38	13.30	17.58
	35-70	20.66	53.16	19.69	27.15	Gravelly sand clay loam	0.73	19.80	1.55	8.30	27.10	14.26	23.55
	70-150	2.02	94.20	2.40	3.40	Sand	0.09	10.50	0.75	8.05	34.10	4.62	23.75
Weighted mean		7.65	83.38	7.43	9.18	Loamy sand	0.26	12.43	0.89	8.07	25.78	8.97	22.84
29	0-25	18.33	66.82	22.51	10.67	Gravelly sandy loam	0.85	9.00	0.49	8.77	58.50	13.14	23.80
	25-55	19.34	96.00	2.10	1.90	Gravelly sand	0.18	12.60	0.49	7.72	6.04	15.52	16.45
	55-150	24.49	97.30	1.65	1.05	Gravelly sand	0.18	7.80	0.50	7.57	5.72	9.77	16.95
Weighted mean		22.43	91.96	5.22	2.82	Gravelly sand	0.29	8.96	0.50	7.80	14.58	11.70	17.99
30	0-20	13.15	92.89	3.31	3.80	Sand	0.58	11.70	0.82	7.33	14.01	12.49	17.78
	20-50	19.80	93.20	2.70	4.10	Gravelly sand	0.46	11.10	0.63	7.48	8.29	9.92	13.10
	50-150	2.19	85.32	7.67	7.01	Loamy sand	0.12	10.80	0.53	7.60	3.64	10.83	22.08
Weighted mean		7.17	87.91	6.09	6.00	Loamy sand	0.25	10.98	0.59	7.54	5.95	10.93	19.71
31	0-40	20.12	63.46	27.32	9.22	Gravelly sandy loam	1.25	11.70	0.00	8.07	1.88	11.97	16.21
	40-65	10.63	87.15	6.03	6.82	Loamy sand	0.18	8.10	0.73	7.36	5.83	10.62	14.54
	65-150	12.44	94.40	1.60	4.00	Sand	0.15	10.80	0.57	7.41	4.20	10.53	8.93
Weighted mean		14.19	84.94	9.20	5.86	Loamy sand	0.45	10.59	0.44	7.58	3.85	11.27	11.81
32	0-15	7.53	86.30	8.49	5.21	Loamy sand	0.49	9.90	0.63	7.40	6.62	10.29	11.36
	15-40	16.46	91.92	3.88	4.20	Gravelly Sand	0.21	13.20	0.64	7.53	4.49	9.20	0.54
	40-60	1.76	69.74	20.24	10.02	Sandy loam	0.15	15.00	0.64	7.67	3.67	11.92	12.42
	60-150	9.70	84.21	9.39	6.40	Loamy sand	0.21	15.90	0.61	7.68	3.97	8.87	10.25
Weighted mean		9.55	83.77	9.83	6.40	Loamy sand	0.23	14.73	0.62	7.63	4.28	9.50	9.03

While the silt fraction percentage ranges between 0.33 and 50.66 % with an average value of 16.53 % and with profiles weighted mean differs between 3.83% and 41.77 %. Whilst the clay fraction percentage ranges from 0.80 to 27.15 % with an average value of 7.38 % and with profiles weighted mean differs between 2.82% and 11.62 %. The texture grade of the examined soil samples was classified as a coarse texture of sand and loamy sand, moderately coarse texture of sandy loam and medium texture of loam and silt loam and moderately fine texture of sand clay loam according to Sys (1979). According to Kumar *et al*. (2009) the organic matter (OM) content of these soil samples was classified as low (<0.86%) to high (>1.29%). It ranges between 0.03 and 1.70% with an average value of 0.34%, whilst the profiles weighted mean differs between 0.07% and 1.33%. Generally, different layers of most soil profiles exhibit no systematic pattern of OM with depth. Total calcium carbonate ($CaCO_3$) content varies widely between 0.60 and 67.00% with an average value of 10.46% and profiles weighted mean ranges from 3.25% to 42.05%. According to the classification prepared by Schoenberger *et al*. (2012), most of these soil samples are moderately calcareous, and strongly calcareous. The concentration of gypsum ranges from nil to 3.33% with an average value of 0.74%, meanwhile the profiles weighted mean ranges from nil to 1.59%. Almost all soil samples have slighty gypsiric (less than 5%) according to FAO (2006). Soil reaction (pH) range between 6.78 to 8.77 with an average value of 7.60 and weighted mean of soil profiles differs among 7.21 and 8.45. Most of the investigated soil samples are slightly alkaline (7.4 to 7.8 pH) according to Schoenberger *et al*. (2012). The EC_e values of these soil profiles vary between 0.52 and 185.20 dS/m with an average value of 18.78 dS/m. However, profiles weighted mean values range from 0.70 to 98.99 dS/m. No clear patterns of EC_e distribution can be noticed with depth in most sites. The cation exchange capacity (CEC) values differ from 2.37 to 15.52 $cmol_c$/kg with an average value of 8.66 $cmol_c$/kg. Moreover, profiles weighted mean values vary from 3.23 to12.27 $cmol_c$/kg. The common low CEC values are due to the dominance of coarse texture and the low organic matter content. No specific pattern of CEC distribution with depth is observed. Exchangeable sodium percentage (ESP) values vary from 0.54 and 23.80% with an average value of 16.64% and weighted mean of soil profiles varies from 6.22 to 22.92%. Most studied soil profiles of the investigated area show an irregular distribution pattern of ESP with depth.

3.2 Land capability evaluation

3.2 Automated Land Evaluation System

The model uses the land use requirements are expressed in terms of land qualities; each one was described by its related land characteristics. For each land characteristics there are four limitation levels with corresponding land classes and rating values as S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable and N = not suitable. Land capability studied depends on some soil properties such as soil depth texture, permeability, available water, slope, drainage, $CaCO_3$, gypsum, soil salinity and alkalinity. The main steps were done to evaluate the area under study matching land use requirements with land qualities using the Automated Land Evaluation Systems (ALES) and displaying the results (Figure 6). The results of the studied area vary from moderately suitable for agricultural to not suitable. The main limitations found in the middle were soil depth, drainage, salinity and soil alkalinity. Automated Land Evaluation Systems (ALES) reveals that these soils could be pleased into the following orders:

Moderate (S2): represented soil profiles (1, 7, 10, 15, 16, 17, 19, 20, 22, 24, 30, 31 and 32). These soils are characterized by deep and moderate, course to moderate coarse texture soils throughout the effective root zone depth, have very few to few gravels content, slight to moderately saline and well to poor drainage.

Marginal (S3): these soils, which were delineated by the soil profiles (4, 12, 13, 21 and 27), are distinguished by deep coarse to moderately coarse texture soils throughout the effective root zone depth, low erosion hazards, moderate to extremely saline conditions and well to poor drainage.

Limited Capability (S4): displayed by soil profiles (2, 5, 11, 18, 23, 25 and 26). These soils have some limitation factors such as: depth, soil texture, stoniness drainage and salinity.

Not suitable (S5): employed by soil profiles (15 and 28), the limitation factors of these soils are slope, soil depth, soil texture, drainage, soil salinity and alkalinity. Some of these limiting factors are correctable such as drainage and salinity. While calcium carbonate content, texture and soil depth are mostly the main limiting factors over all the study area. Some can be mitigated or improved by applying the appropriate soil management practices, these soil management practices including improvement of the drainage, deep plowing or sub-soiling to improve soil permeability and moisture availability, organic fertilization to improve permeability, CEC and nutrient availability, applying modern irrigation systems and reducing the irrigation periods.

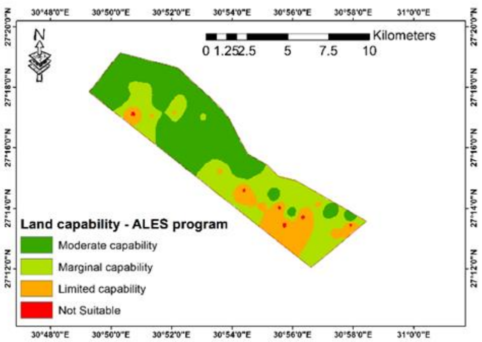

Figure (6): Land capability classification of the study area using ALES program.

3.2.2 MicroLEIS (Cervatana model)

The results of land capability of the investigated area using MicroLEIS-Cervatana model are present in Table (5) and illustrated in Figure (7). These findings show that these soils could be placed into the following orders and classes:

Good class (S2): Around 25% of the total soil profiles in the studied area are good class. The soils of this class are described by soil profiles 6, 13, 17, 18, 22, 26, 31 and 32.

Moderate class (S3): About 34.38% of the total soil profiles in the studied area are moderate class. The soils of this class are described by soil profiles 1, 4, 7, 10, 12, 15, 16, 19, 20, 24 and 30.

Marginal class (N): Approximately 40.62% of the total soil profiles in the studied area are marginal class. The soils of this class are described by soil profiles 2, 3, 5, 8, 9, 11, 14, 21, 23, 27, 28 and 29.

Table (5): Land capability of the study area (MicroLEIS-Cervatana model).

Order	Classes	Soil Profiles	Area (%)
S	S2	(6, 13, 17, 18, 22, 26, 31 and 32)	25
S	S3	(1, 4, 7, 10, 12, 15, 16, 19, 20, 24 and 30)	34.38
N	N	(2, 3, 5, 8, 9, 11, 14, 21, 23, 27, 28 and 29)	40.62

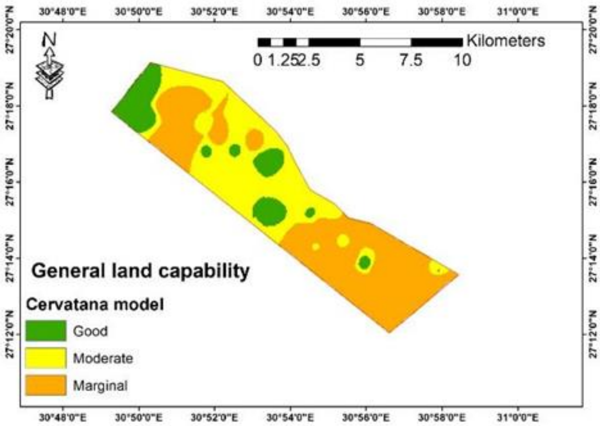

Figure (7): Land capability classification of the study area using MicroLEIS - Cervatana model.

Finally, to find the best priorities of agricultural land use within the studied area, the soils have been evaluated using the land capability systems. These systems are based on the following parameters such as slope, topography, depth, texture, calcium carbonate content, gypsum content, salinity and alkalinity, cation exchangeable capacity, exchangeable sodium percentage and sodium adsorption ratio. Based on the actual soil properties, land capability for agricultural production was assessed using the ALES and Micro-LEIS systems. Results indicate that the area currently lacks high capability and land capability for the most systems range between moderate or marginally suitability classes and non-suitable. The main results for the analysis of soil characteristics and the application of tools for land capability evaluation are powerful tools for decision-making and can be used as a decision support system.

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