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Assessment of Some Different Methods of Classifying Land Suitability for Crop Cultivation, Central Sinai, Egypt

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ABSTRACT

Soil assessment plays a pivotal role in the development of sustainable agriculture to achieve highest productivity and lowest environmental menaces. The research aims to assess land for suitable agricultural use in the area of El-Gifgafa - central Sinai for sustainable agricultural development. In addition, a comparison of the land quality classification for different crops using Sys system and ALMAGRA model. The area of study is between 30 ° 11 'to 30 ° 27' N latitude and 33 ° 15 'to 33 ° 24 E longitude, it covers around 80.000 feddan. The North-Western and Middle of Sinai in Egypt located in Mediterranean region. Based on the geomorphological formation achieved in the area, the study area includes the alluvial plain, alluvial terraces, Wadi deposits, pediplain and rock out crops. The physical land suitability assessment, applied and described in this research, is reliant on globally acknowledged methods for arid and semi-arid areas of the Mediterranean region. Results indicated that the area under investigation currently lacks high suitability for permanent crops where most land use systems fall into the categories of moderate or/ marginal suitability classes and non-suitable. Land suitability results for crops according to limiting factor method determined by Sys *et al*. (1993, part III) ranged from moderately suitable (S2) and permanently non-suitable (N2), while in accordance with MicroIIES model (ALMAGRA) land suitability were moderately suitable (S3), marginally suitable (S4) and non-suitable (S5). Alluvial plain mapping unit has a very small area moderately suitable to citrus

***Keywords**:* Sys model, ALMAGRA model, Central Sinai, El-Gifgafa region

INTRODUCTION

In Egypt, the motivation behind soil reclamation projects is to expand Egypt's rare arable land and make it capable of feeding an ever-growing population (Pautsch and Abdelrahman, 1998; Abo Shelbaya, *et al*., 2021). According to (Rossiter, 1990), one of the most important tasks of development scholars is to interpret and manage resource inventories for land users and planners. These teams should show the suitability of the land resources for the actual and projected uses of the land, in the face of urgent needs. Egypt has become and is still dependent on the imported commodities, so a number of experts agree that this problem could be largely revived if desert land outside the Egyptian Nile Delta was cultivated. However, in the modern world, with rapid population growth and increasing environmental degradation, changes in land use must be made faster, hence the need for land use planning or re-planning at the national, regional and local levels (Shalaby and Tateishi, 2007; Ismail, *et al*., 2010; Abd El-Azeim, *et al*., 2020). Thus, the agricultural expansion in the northeastern coastal region and central Sinai is one of the main objectives of the Egyptian policy to meet the food security needs of the massive increase in population (Ismail, *et al*., 2010).

Soil assessments play a significant role in the development of sustainable farming systems. On the basis of the value of several soils and environmental indicators, the agricultural land assessment procedure is applied to land mapping units in order to calculate the land suitability index (Sayed, 2013). The fundamental purpose of the land evaluation is to predict the results of modification. Land analysis becomes necessary wherever modification is contemplated. This could be a modification in a similar way of use, or it should be the introduction of a replacement technique. Prediction is required for the quality of the land for various styles of production, the inputs, and management practices required for the assembly or different edges, and also the consequences of such changes upon the surroundings (Dent and Young, 1981).

According to Abdel Kawy, *et al*. (2010), remote sensing and geographical information system (GIS) were used to produce a soil map and assess the present and potential suitability of crops in Sahel al-Tineh - South Qantara East region, North Sinai. The present suitability specifies that the area of Sahel al-Tineh has a marginal suitable for alfalfa and not suitable for peach, citrus or olive trees. Sahel al-Tineh area has limited suitability by soil edaphic factors of high soil salinity and shallow soil depth. The area of South El-Kantara Shark is moderate to marginal suitable for alfalfa, peach, citrus and olive trees. The main determinants factors of suitability in South El-Kantara Shark area were soil texture and nutrient availability.

Land suitability analysis was done using remote sensing data and GIS technique for an area in Southwest Sinai that includes Wadi Baba, Wadi El-Bidaa, Wadi Naga El-Gada and Elwet Baba. Mapping the land suitability based on evaluating soil chemical and physical attributes versus each cropping pattern requirements using the Micro-LEIS Almagra software. The specified crops are: wheat, maize, potato, soybean and sunflower (as annual crops); and alfalfa (as semiannual crops), peach, citrus and

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olive (as perennial crops). The most limiting factors were soil texture, followed by salinity, sodium saturation, and lime content. The results of this study revealed that south west Sinai of Egypt has the potentiality for agricultural land use where about 45.72% of the total studied area is highly suitable (S2) to moderately suitable (S3) for the selected crops, while 54.28% of the total studied area is not suitable (S5) for them, (Abd El-Maaboud, *et al*., 2018)

According to Sayed, (2013), land suitability for crops, as stated by (ALMAGRA) is highly suitable (S1), suitable (S2), moderately suitable (S3), marginally suitable (S4) and non-suitable (S5). The adequacy of the land of the El-Hammam canal and the extension for the greater adequacy of some crops could be categorized as olive, citrus and alfalfa and are between suitable (S2) and unsuitable (S5). Hamied, (2009) reported that the soils of the Giza Governorate, Egypt classified by the MicroLIES model ranged between high and marginally suitable for citrus and olive, while it is ranged between high and moderate for alfalfa.

Besides, owing to Egypt's rapid urbanization and development, the need to create jobs and redistribute the population has become a top priority for the Egyptian authorities. On the other hand, the establishment of new infrastructure and industrial zones in the Sinai Peninsula can contribute to solving the problem. The potential for agricultural reclamation is low and will depend on finding a moderate-to-large quantity of good quality groundwater. Agriculture will continue to be restricted to the wadi plains. Based on existing roads and natural resources, it appears that El-Gifgafa is more likely to be the settlement base for the exploitation of reclamation and sustainable development plan (Effat, 2014). Future agricultural development depends largely on the introduction of large amounts of irrigation water. Whereas, present-day agriculture in this province includes date palms in the depressions between sand-dunes and near the coast; dispersed rainfed farming systems consisting primarily of watermelon, several vegetables, and some barley; and a limited number of drip-irrigated crops near El Arish (Omran, 2017). Abd El-Maaboud, *et al*. (2018) showed, land suitability results for cultivating some specific crops in different valleys of southwest Sinai exposed that about 45.72% % of the investigated area is high to moderately high of land suitability for particular crops. The main suitability limitations were soil texture, carbonate content, salinity, or sodium saturation. Also, the land suitability analyses showed that the study area is suitable for cropping alfalfa, peach, citrus and olive. The study area is of moderate capability for horizontal expansion.

Managing the natural resources of land and water in arid and semi-arid regions is critical and unlocks the way for new agricultural expansion and activities and the growing of inhabited societies. The Sinai Peninsula incurs from water shortage, which limits these types of development significantly. The future of land reclamation in the Sinai will depend to a large extent on the potential of the groundwater and the mega projects to extend the irrigation canals. The potential for agricultural reclamation is low and will depend on finding a moderate-to-large quantity of good quality groundwater. Agriculture will continue to be restricted to the wadi plains. Based on existing roads and natural resources, it appears that El-Gifgafa is more likely to be the settlement base for the exploitation of reclamation and sustainable development plan.

This research aims at evaluating lands for acceptable agricultural use within the El-Gifgafa region, Central Sinai for agricultural development. Additionally, to a comparison of land quality classification for various crops using (Sys 1993 system and ALMAGRA model)

MATERIALS AND METHODS

Space-based multi-criteria assessment has been widely used to determine land use according to its capability and constraints. Using the Shuttle Radar Survey Flight, digital elevation model, weather data and distinct land-use data Shuttle Radar Topography Mission (SRTM). Soil survey and land assessment for sustainable agricultural production by Sys and Micro-LEIS Almagra software

Study area description and field work

In the northeastern part of Egypt, Sinai Peninsula lies between longitudes 32 ° 20'-34 ° 52 'E and latitudes 27 ° 45'-31 ° 10' N, and covers an area of about 6% (61,000 km^2) of the total area of Egypt. The study area is located between 30 ° 11 'to 30 ° 27' N latitude and 33 ° 15 'to 33 ° 24 E longitude (Figure 1). It covers around 120.000 feddan. Twenty-four soil profiles represent the realm beneath study were chosen on the basis of obtainable structural geomorphological mapping units, Figure 2. Soil profiles representing the study area were selected using available geomorphological information. These profiles have been dug to a depth of 150 cm, unless they are opposed by a rocky substrate or an extremely hard layer. Soil morphological description was performed according to the criteria established by Field Book for Describing Soil Samples (Schoeneberger, *et al*., 2002, 2011 and 2012) and FAO (Guidelines for soil description 1990 and 2006). The soil samples collected, which amounted to 64, represented the resulting morphological variations across the depth of the soil profiles.

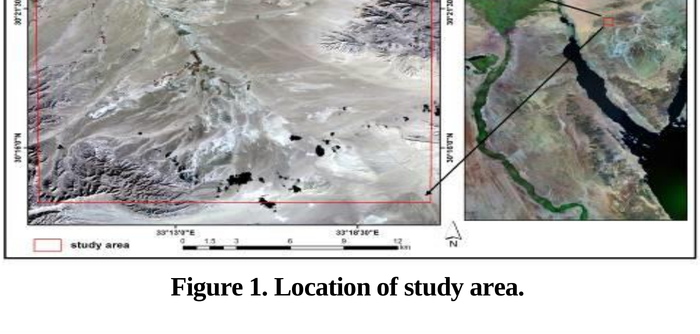

Figure 1. Location of study area.

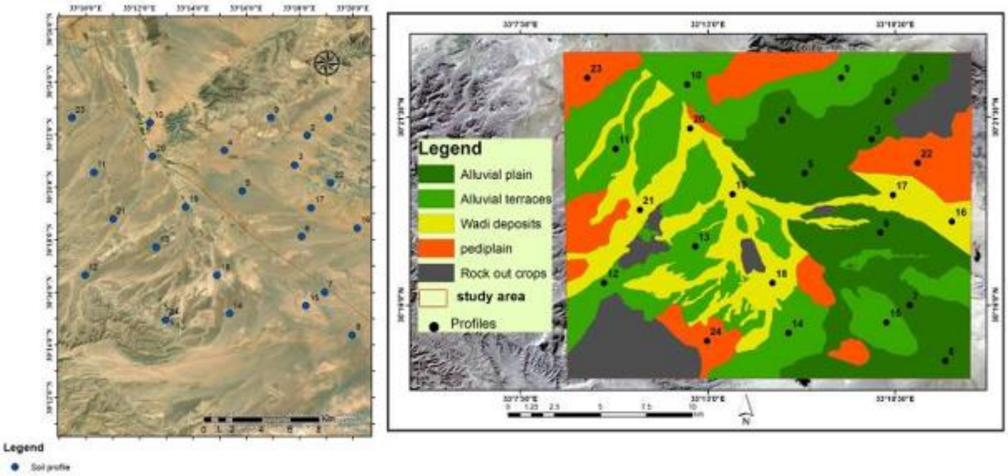

Figure 2. Location of soil profiles and geomorphological mapping units.

The climate of the peninsula plays a significant role in shaping the Sinai landscape and controlling the ecology of the peninsula. Climate conditions in the study area are generally arid, characterized by a long, warm, dry summer, a mild winter with little precipitation, high evaporation with moderate to high relative humidity. The maximum temperature (34 and 20.5 °C) is recorded in August, while the minimum (17.5 and 4.5 °C) is recorded in January. According to (Omran, 2017), the northern strip of Sinai receives maximum precipitation during the winter (200 to 300 mm/year), and this quantity decreases towards the south (25 mm/year). In parched zones, for example, Sinai in Egypt, precipitation is mostly brought about by gust line and convective cloud instruments and by low-force frontal downpour, causing storm floods (El Afandi, *et al*., 2013) and (Baldi, *et al*., 2020).

Water resources in Sinai are dependent on precipitation, sources, mixing of the Nile and drainage water, some springs have been discovered in northern and central Sinai. A mixture of Nile water and drainage water, carried through the El-Salam channel (Omran, 2017). Area of the study is covered by the Quaternary deposits, Upper Cretaceous, Lower Cretaceous and Jurassic rocks, (Elewa, *et al*., 2012). The general geologic section comprises basement rocks represented by Precambrian schist, gneisses, granites and diorites covered by a thick sedimentary cover of limestones, sandstones, shale, marls, and clays of Permo Carboniferous, Triassic, Jurassic, and Cretaceous (Said, 1962). The unity of the quaternary sediment area represented by gravel, sand, silt and calcareous rock fragments in addition to sand dune accumulations. The thickness of these deposits varied between some 1.0 m and about 30 meters.

Laboratory analysis

Disturbed soil samples were collected, then air-dried, ground gently and sieved through a 2 mm sieve to prepare them for soil analyses. Soil physicochemical properties were determined in accordance with soil analyses methods by Richards, (1954); Page *et al*., (1982) and Avery and Bascomb, (1982). Mechanical analysis and particle size distribution was conducted by dry sieving for coarse textured samples and calcium carbonate content was estimated volumetrically using Collin's Calcimeter, (Piper, 1950). Soil pH, soil salinity, and soluble cation and anion were determined from the soil extract. Total organic content in the soil samples was carried out by Walkley and Black titration method by Day and Black, (1982).

Land Suitability Classification for Different Crops, (Sys model, 1993)

In this research, an approach was adopted to assess the suitability of the land in the study area, which is the Sys 1993 system and the ALMAGRA model, as it is suitable and valid for irrigation in arid and semi-arid regions. Through this approach, classification has been treated in accordance with the FAO framework (1976), at class and subclass level. In addition, Sys, 1993 system was used to assess study area soils for the promising crops for cultivation. The main process of qualitative suitability of the land to crops, relies on the soil physicochemical characteristics (soil stones content, soil texture, profile depth, soil structure, gypsum and calcium carbonate content and state). The ratings, ascribed to land qualities, were corresponding to each crop requirement. These land qualities are soil drainage capacity, soil texture, soil gravel percentage, soil profile depth, $CaCO_3$ content, soil salinity (EC), soil pH, soil sodicity namely exchangeable sodium percentage (ESP) and soil fertility features. Assessment procedures were accomplished by matching the land properties /qualities against the crop requirements (LUT) using limitation method approach with a criteria number and limitation intensity. Limitation degree, limitation intensity and classes are explained in Table 1.

Table 1. Degree of limitations, intensity of limitations and classes

Suitability class	Intensity of limitation	Defined class
S1	No	Very suitable
S2	Slight	Moderately suitable
S3	Moderate	Marginally suitable
N1	Severe	Actually, unsuitable and potentially suitable
N2	Very severe	Actually, unsuitable and potentially unsuitable

Agricultural soil suitability model (ALMAGRA)

The ALMAGRA model is counted on the soil analysis of edaphic factors that affect productivity of semi-annual crops such as alfalfa and permanent crops like peach, citrus and olive. The edaphic soil factors including the effective soil profile depth (p), soil texture (t), soil drainage (d), soil carbonate content (c), soil salinity (s), sodium saturation (a) and degree of profile development

(g) are used as diagnostic criteria (MicrolIES web) and (Aldabaa, *et al*., 2010), (Table 2).

Table 2. Soil suitability classes, limitations and soil edaphic factors definitions.

Soil suitability class		Soil factor		
Symbol	**Definition**	**Definition**	**Symbol**	**Definition**
S1	Highly suitable	None	a	Sodium saturation
S2	Suitable	Slight	c	Carbonate
S3	Moderately suitable	Moderate	d	Drainage
S4	Marginally suitable	Sever	g	Profile development
S5	Not suitable	Very sever	p	Useful depth
			s	Salinity
			t	Texture

RESULTS AND DISCUSSION

Soil Properties

Based on the geomorphological formation achieved in the area, the study area includes the alluvial plain, alluvial terraces, Wadi deposits, pediplain and rock out crops. The morphological, physicochemical characteristics of each soil mapping unit are given in Table 3.

Table 3. Soil mapping units based on the geomorphological formation

No.	Unit	(Area) feddan	(Area)km^2	%
1	Alluvial plain	20686	87	25.9
2	Alluvial terraces	24963	105	31.3
3	Pediplain	11975	50	15.0
5	Wadi deposits	14357	60	18.0
4	Rock out crops	7810	33	9.8

Alluvial plain unit

This unit of soil mapping occupies an area of about 20686.0 feddan and is referred to by soil profiles 1, 2, 3, 4, 5, 6,7 and 8. Their analytical data are given in the following Table (4). The common features of the produced soil mapping unit are deep (120 cm.), coarse texture (sand to loamy sand) sometimes with moderately fine to moderately coarse texture (sandy clay loam to sandy loam) and somewhat excessively drained to well drained. These soils are slightly calcareous to extremely calcareous, where calcium carbonate content varies from 3.57 to 75.5 %, the highest contents are mostly detected in deepest layers and increased with the surface layers. The highest values of calcium carbonate are detected with soil profiles closed to high land and rock outcrops. Soil reaction is slight to strongly alkaline, as specified by pH values ranged from 7.25-8.55. Electrical conductivity of the soil saturation extract varies from 0.76 to 62.10 dSm^{-1}, indicating non-saline to extremely saline condition. Depth distribution of the soil electrical conductivity is asymmetrically distributed with respect to the depth and location of the soil profiles. This is anticipated owing to the formation of soils from different parent materials of heterogonous nature and/or multi-depositional regimes.

Table 4. Analytical data represented the soil profiles of the study area.

Profile	Depth	$CaCO_3$	Soil Bulk Density	Particle size distribution (%)			Soil	pH	EC	O.M
No.	**(cm)**	**%**	**gcm^{-3}**	**Sand**	**Silt**	**Clay**	**Texture**	**1:2.5**	**dSm^{-1}**	**%**
				Alluvial plain (20686 feddan)						
1	0-20	27.30	1. 59	88.37	6.89	4.65	Sand	7.38	14.95	0.12
	20-70	28.90	1.46	91.54	4.48	3.98	Sand	7.35	0.81	0.09
	70-120	75.50	1.59	92.52	4.72	2.76	Sand	7.29	2.70	0.05
2	0-10	23.10	1.48	80.90	14.30	4.80	Loamy sand	7.90	7.90	0.12
	10--60	68.60	1.39	85.30	10.60	4.00	Loamy sand	7.60	1.42	0.13
	60-120	74.00	1.61	84.80	13.70	4.50	Loamy sand	8.00	35.30	0.13
3	0-10	7.25	1.34	87.11	5.87	7.02	Loamy sand	7.25	47.50	0.19
	10--90	7.28	1.65	92.70	1.09	6.21	Sand	7.28	62.10	0.12
	90-120	10.20	1.54	90.94	2.98	6.08	Sand	7.60	21.30	0.07
4	0-10	7.06	1.54	63.50	35.00	1.50	Sandy loam	8.55	1.80	0.25
	10--60	5.33	1.66	61.50	34.50	4.00	Sandy loam	8.50	1.42	0.11
	60-120	7.01	1.54	43.50	46.50	10.00	Loam	8.55	0.76	0.11
5	0-15	6.93	1.46	45.50	50.50	4.00	Silt loam	8.55	10.82	0.20
	15-30	3.69	1.51	51.50	43.50	5.00	Sandy loam	8.30	25.40	0.15
	30-70	4.41	1.56	55.50	39.50	5.00	Sandy loam	8.30	14.40	0.11
	70-120	6.72	1.65	55.50	41.50	3.00	Sandy loam	8.40	12.00	0.11
6	0-15	22.40	1.54	74.00	17.50	8.50	Sandy loam	8.00	1.38	0.15
	15-50	7.30	1.61	77.70	15.80	6.50	Loamy sand	8.20	2.45	0.07
	50-120	28.00	1.46	77.70	15.80	6.50	Loamy sand	7.40	7.10	0.07
7	0-25	8.74	1.34	55.50	38.50	6.00	Sandy loam	8.45	5.20	0.27
	25-50	4.41	1.51	55.50	37.50	7.00	Sandy loam	8.50	13.38	0.15
	50-120	3.57	1.38	53.50	41.50	5.00	Sandy loam	8.48	11.60	0.15
8	0-20	30.00	1.38	54.60	23.30	22.50	Sandy clay loam	7.60	1.10	0.11
	20-40	16.10	1.39	82.60	12.60	4.80	Loamy sand	7.50	11.63	0.13
	40-70	16.10	1.56	84.60	12.30	4.00	Loamy sand	7.50	11.63	0.17
	70-120	75.00	1.56	86.60	10.30	4.00	Loamy sand	7.80	2.07	0.17
				Pediplain (11975 feddan)						
22	0-20	35.20	1.56	85.10	13.10	1.80	Loamy sand	7.70	3.60	0.12
23	0-35	21.50	1.39	90.00	4.50	5.50	Sand	7.60	4.20	0.21
24	0-30	15.30	1.56	87.00	10.00	3.00	Sand	7.50	3.90	0.13

Table 4. cont.

Profile No.	Depth (cm)	$CaCO_3$ %	Soil Bulk Density gcm^{-3}	Particle size distribution (%) Sand	Silt	Clay	Soil Texture	pH 1:2.5	EC dSm^{-1}	O.M %
				Alluvial Terraces (24963 feddan)						
9	0-15	30.80	1.39	83.00	13.50	3.50	Loamy sand	7.60	4.50	0.11
	15-60	85.00	1.60	80.80	14.20	5.00	Loamy sand	7.50	4.10	0.15
10	0-10	67.50	1.39	88.25	5.87	5.88	Loamy sand	7.42	66.15	0.18
	10--40	67.50	1.41	87.06	6.84	6.10	Loamy sand	7.42	66.15	0.06
	40-120	64.30	1.41	87.06	6.84	6.10	Loamy sand	7.39	63.20	0.06
11	0-20	38.50	1.35	87.19	6.04	6.77	Loamy sand	7.48	3.80	0.20
	20-40	32.10	1.45	85.41	6.67	7.92	Loamy sand	7.46	3.92	0.14
12	0-30	25.70	1.39	89.22	5.04	5.74	Sand	7.51	20.20	0.30
	30-70	61.10	1.45	90.75	3.88	5.37	Sand	7.53	7.60	0.16
	70-120	73.90	1.54	90.65	3.33	6.02	Sand	7.55	5.11	0.10
13	0-25	6.59	1.30	67.50	30.50	2.00	Sandy loam	8.30	26.60	0.16
	25-80	3.28	1.34	63.50	33.50	3.00	Sandy loam	8.50	23.00	0.12
	80-120	4.96	1.45	65.50	33.50	1.00	Sandy loam	8.40	26.00	0.09
14	0-15	8.19	1.39	47.50	51.00	1.50	Silt loam	8.50	21.80	0.25
	15-70	3.86	1.57	43.50	54.00	2.50	Silt loam	8.10	35.40	0.15
	70-120	7.73	1.65	56.50	42.00	1.50	Sandy loam	8.20	27.20	0.12
15	0-15	44.10	1.66	79.30	15.00	5.60	Loamy sand	7.90	13.71	0.13
	15-40	15.40	1.55	79.30	16.00	4.70	Loamy sand	7.80	7.66	0.09
	40-120	21.00	1.56	78.40	14.30	7.30	Loamy sand	7.90	2.00	0.15
				Wadi deposits (14357 feddan)						
16	0-15	3.91	1.58	57.50	40.00	2.50	Sandy loam	8.40	7.42	0.23
	15-120	6.93	1.35	53.50	43.00	3.50	Sandy loam	8.30	12.00	0.15
17	0-20	5.96	1.39	55.50	42.00	2.50	Sandy loam	8.50	21.80	0.20
	20-40	4.12	1.60	53.50	43.00	3.50	Sandy loam	8.20	36.00	0.18
18	0-10	6.64	1.39	53.50	44.50	2.00	Sandy loam	8.50	26.00	0.30
	10--50	3.69	1.39	55.50	42.00	2.50	Sandy loam	8.40	36.00	0.25
	50-120	6.22	1.57	55.50	41.50	3.00	Sandy loam	8.10	21.80	0.20
19	0-25	7.31	1.39	52.50	45.00	2.50	Sandy loam	8.20	30.44	0.21
	25-50	7.31	1.48	47.50	50.00	2.50	Silt loam	8.20	30.44	0.13
	50-80	4.54	1.61	43.50	53.00	3.50	Silt loam	8.55	16.72	0.09
	80-120	5.12	1.54	43.50	53.50	3.00	Silt loam	8.50	15.00	0.09
20	0-55	40.10	1.62	91.56	3.21	5.23	Sand	7.28	33.20	0.15
	55-120	67.50	1.44	92.90	2.99	4.11	Sand	7.31	34.45	0.06
21	0-10	8.06	1.39	91.84	3.18	4.98	Sand	7.28	11.00	0.18
	10--50	40.20	1.45	91.31	2.55	6.14	Sand	7.21	55.40	0.12
	50-120	64.30	1.55	92.97	3.72	3.31	Sand	7.19	33.10	0.08

Pediplain unit

This mapping unit covers an area of approximately 11975.0 feddan of uncultivated land. The common features of this soil mapping unit are very shallow to shallow soils (20 to 35 cm.). The soils are coarse-textured (sand to loamy sand). Calcium carbonate contents are mostly high to very high (15.3 - 35.2 %). Soil pH is slightly too alkaline (pH values 7.5 - 7.7). EC values range between 3.6. and 4.2 dSm^{-1}, indicating slightly to moderately saline soils.

Alluvial terraces unit

The soils in this mapping unit cover about 24963.0 feddan, represented by soil profiles 9, 10, 11, 12, 13, 14 and 15. The common characteristics of these soils are shallow to deep profiles where the effective soil depth varies from 40-120 cm, soil texture throughout the entire depth of the studied soil profiles is sand to sandy loam sometimes with silty loam of profile 14 surface. Table (4 cont.,) shows that these soils are slightly calcareous to extremely calcareous, where calcium carbonate content varies widely from 3.28 to 85.0 %, and the highest carbonate contents are detected in the sub surface and surface layers. Soil reaction varies from mildly alkaline to alkaline, as designated by pH values which range from 7.39 to 8.5. Soil salinity varies widely from one profile to another, where data indicated that the shallow and moderate soil profiles (9 and 11). EC values range between 3.8 and 4.5 dSm^{-1}. On the contrary, the deep soil profiles are salt-free to extremely saline (2.0 -66.5 dSm^{-1}). Soluble salts high concentrations in some soil profile layers indicates that leaching or deletion of excess salts all over the subsequent layers is necessary, and this could be happened quite easily because of the fragile and open structure of the studied soils. Organic matter percentage levels are very low in the rhizosphere area and the topmost soil layers ranging from 0.09 to 0.30 %.

Wadi deposits unit

This land mapping unit covers approximately 14357.0 feddan area. It is represented by soil profiles No. 16, 17, 18, 19, 20 and 21. Common features of these soils are the deep profile (120 cm), with the exception of Profile No. 17, shallow soils (40 cm). Soils of coarse texture through certain deep (sand) or medium coarse (sandy loam) soil profiles with No. 19 medium to coarse sand infill profile. And these soils are well drained or poorly drained. The calcium carbonate content varies from 3.91 to 67.5%, and the highest levels are usually detected in the deepest layers of profiles 20 and 21. Consequently, these soils are non-calcareous to extremely calcareous. The soil response is slightly to strongly alkaline, as indicated by pH values varying from 7.28 to 8.55. Soil salinity varies considerably from (7.42 to 55.4 dSm^{-1}) moderate to extremely saline. The higher concentration of soluble salts in certain soil layers dictates that leaching or removal of excess salts in subsequent layers is a must. This could be done rather easily due to the open structure of the soils.

Characterization of weighted mean soil properties

The major of weighted mean soil physical, chemical and physicochemical are determined and presented in Table 5. The common characteristics of this soil are very shallow to profound (20-150 cm), FAO 2006, a sandy-to-sandy loam - loamy texture with calcium carbonate slightly to very contained and poorly to well drained. The distribution of weighted average soil salinity (EC) values is provided in Table 5. Weighted mean values of soil salinity ranged widely from 3.9 to 50.68 dSm^{-1}. Soil salinity is a major influencing factor that limits the distribution of plant communities in their natural environments and is causing increasingly serious agricultural problems (Abd El-Azeim *et al*., 2020). Electric conductivity and soil reaction are important soil edaphic factors because it affects soil fertility, nutrient availability, microbial activity and plant production and quality. The weighted average soil reaction varies considerably between 7.21 and 8.56, indicating a slightly alkaline to strongly alkaline soil reaction (Schoeneberger *et al*., 2002). Characteristics of soils in this mapping unit dictate that soil cation exchange capacity (CEC) values are low to moderate and coincide well with soil texture, being in the range between 7.2 and 14.25 $Cmol_c\ Kg^{-1}$ soil.

Table 5. Weighted mean soil properties of the illustrative soil profiles

Mapping Unit	Profile NO	Depth cm.	$CaCO_3$ %	Sand %	Silt %	Clay %	pH	EC dSm^{-1}	O.M %	ESP %	CEC Cmolc Kg^{-1} soil
Alluvial plain	1	150	48.05	91.40	4.98	3.62	7.36	3.96	0.08	6.41	8.13
	2	130	67.51	84.68	12.46	4.32	7.83	18.89	0.13	15.24	12.59
	3	120	8.03	91.78	1.98	6.24	7.38	50.68	0.11	18.75	9.49
	4	130	6.30	52.67	40.54	6.79	8.56	1.13	0.12	4.70	13.94
	5	135	5.58	53.75	42.21	4.04	8.38	14.33	0.13	11.60	12.47
	6	120	21.26	77.24	16.01	6.75	7.71	5.05	0.08	9.18	9.91
	7	130	4.83	54.33	40.04	5.63	8.50	10.64	0.18	10.51	13.33
	8	135	42.96	80.10	13.35	7.22	7.64	5.89	0.15	9.53	14.17
Alluvial Terraces	9	60	71.45	81.35	14.03	4.63	7.53	4.20	0.14	9.23	12.80
	10	120	65.37	87.20	6.73	6.08	7.40	64.20	0.07	31.33	13.58
	11	40	35.30	86.30	6.35	7.35	7.50	3.85	0.17	8.00	14.25
	12	120	57.58	90.36	3.93	5.73	7.54	9.71	0.17	12.78	8.91
	13	120	4.55	65.00	32.88	2.13	8.43	24.75	0.12	15.82	11.41
	14	120	6.02	49.42	48.63	1.96	8.19	30.28	0.15	16.30	11.33
	15	135	22.72	78.70	14.74	6.55	7.88	4.65	0.14	8.49	12.35
Wadi deposits	16	120	6.53	54.00	42.63	3.38	8.31	11.43	0.16	10.78	12.13
	17	40	5.05	54.50	42.50	3.00	8.35	28.90	0.19	15.80	11.90
	18	120	5.40	55.33	41.92	2.75	8.23	26.88	0.23	14.83	11.75
	19	120	5.87	46.21	50.88	2.92	8.40	21.84	0.12	14.20	11.85
	20	120	65.22	92.79	3.02	4.19	7.30	34.39	0.07	24.48	8.33
	21	120	51.58	92.33	3.29	4.38	7.21	38.69	0.10	34.55	8.42
Pediplain	22	20	35.20	85.10	13.10	1.80	7.70	3.60	0.12	8.80	11.20
	23	35	21.50	90.00	4.50	5.50	7.60	4.20	0.21	13.70	8.80
	24	30	11.50	10.00	3.00	1.60	7.50	3.90	0.13	7.90	7.20

Land suitability for specific crops

Based on the attained results, the following land suitability classes have been proposed:

Land Suitability Classification for Different Crops, (Sys model).

The degree of limitation and the level of limitation are listed in the Table 1. In order to identify the current suitability, limiting factor, land improvement and future suitability, three crops were selected and assessed rendering to their wants with the land properties of the mapping units. The following land suitability classes are proposed based on the obtained results:

Moderately suitable land (S2)

Soils of this suitability class cover a small area in the area under investigation (Table 6 and Figures 3 and 5), which could be cultivated with olives and alfalfa. This soil was seen in alluvial plain and wadi deposits units.

Marginally suitable land (S3):

These soils have moderate-severe limits, e.g., soil depth, textural, salinity, and calcium carbonate levels. Alluvial plain mapping unit has very small area represented by (profiles 6 and 7) are moderately suitable to citrus (Figure 4), and alfalfa respectively. These soils could be cultivated with citrus and alfalfa in the alluvial terraces and wadi deposit units, where the soils of this class cover a very small area, (Table 6).

Currently not suitable land (N1):

This implicates lands with limitations and restrictions that are too severe to be economically corrected with available knowledge.

Permanently not suitable land (N2):

The limitations on these soils are too severe to prevent any prospects for a successful sustainable use of the land. These soils have so severe limits, e.g. soil depth and high calcium carbonate levels.

Table 6. Land suitability for crops using Sys, model and ALMAGRA model for semi-annual and perennial crops.

Mapping unit	Profile Land suitability for crops (Sys, model)				Agricultural soil suitability (ALMAGRA model)		
	No	Alfalfa	Citrus	Olive	Alfalfa	Citrus	Olive
Alluvial plain	1	N2c	N2c	S2t	S5t	S4t	S3t
	2	N2cs	N2cs	S3s	S5ts	S5s	S5s
	3	N2s	N2s	N2s	S5ts	S5s	S5s
	4	S2t	S2t	S2t	S4t	S3t	S3t
	5	N2s	N2s	S2ts	S4ts	S5s	S5s
	6	S2c	S3cs	S2t	S4t	S3ts	S3ts
	7	S3s	N2s	S2t	S4t	S5s	S3ts
	8	N2c	N2c	S2t	S4t	S3tcs	S3ts
Alluvial Terraces	9	N2c	N2dc	N2d	S5t	S5t	S4ptd
	10	N2c	N2c	N2s	S5tsa	S5sa	S5sa
	11	N2c	N2dc	N2d	S5t	S5ptd	S5pd
	12	N2c	N2c	S2t	S5t	S5s	S3tcs
	13	N2s	N2s	N1s	S5s	S5s	S5s
	14	N2s	N2s	N2s	S5s	S5s	S5s
	15	S2c	S3cs	S2t	S5t	S4t	S3ts
Wadi deposits	16	S3s	N2s	S2t	S4ts	S5s	S5s
	17	S3ds	N2s	N2d	S5ts	S5pds	S5pds
	18	N2s	N2s	N1s	S5s	S5s	S5s
	19	N2s	N2s	N1s	S5s	S5s	S5s
	20	N2c	N2s	N2s	S5ts	S5s	S5s
	21	N2s	N2s	N2s	S5tsa	S5sa	S5sa
Pediplain	22	N2dc	N2dc	N2d	S5pt	S5ptd	S5pd
	23	N2d	N2d	N2d	S5pt	S5ptd	S5pd
	24	N2d	N2d	N2d	S5pt	S5ptd	S5pd

S1= highly suitable, S2= moderate suitable, S3= marginally suitable, N1= currently not suitable, N2= permantly not suitable d= soil depth t=Texture c=Carbonate s = Salinity

Limitations: 1=No; 2=Slight; 3=Moderate; 4=Severe; 5=Very severe. p=Useful depth t=Texture d=Drainage c=Carbonate s = Salinity a= Sodium sat g=Profile dev

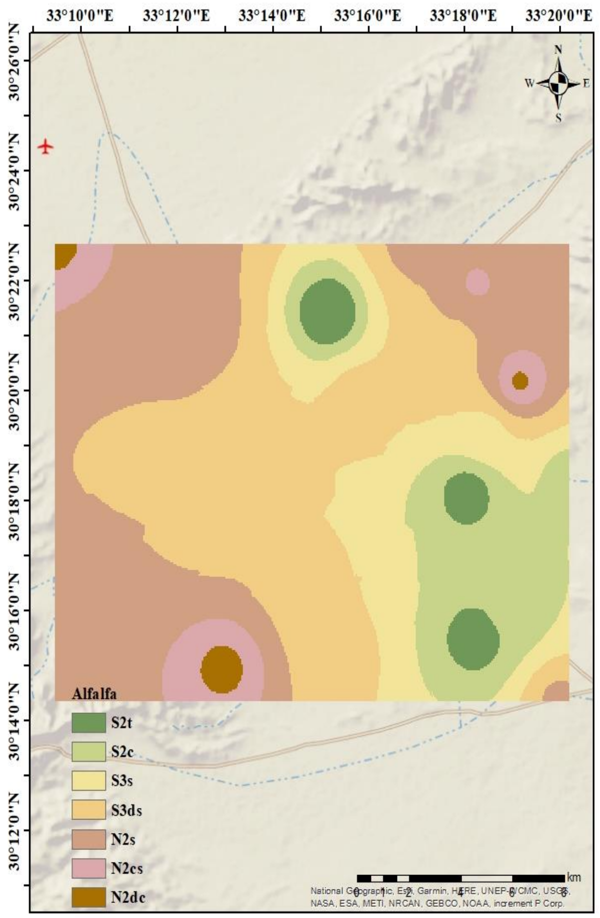

Figure 3. Land suitability for Alfalfa crops. (Sys, model).

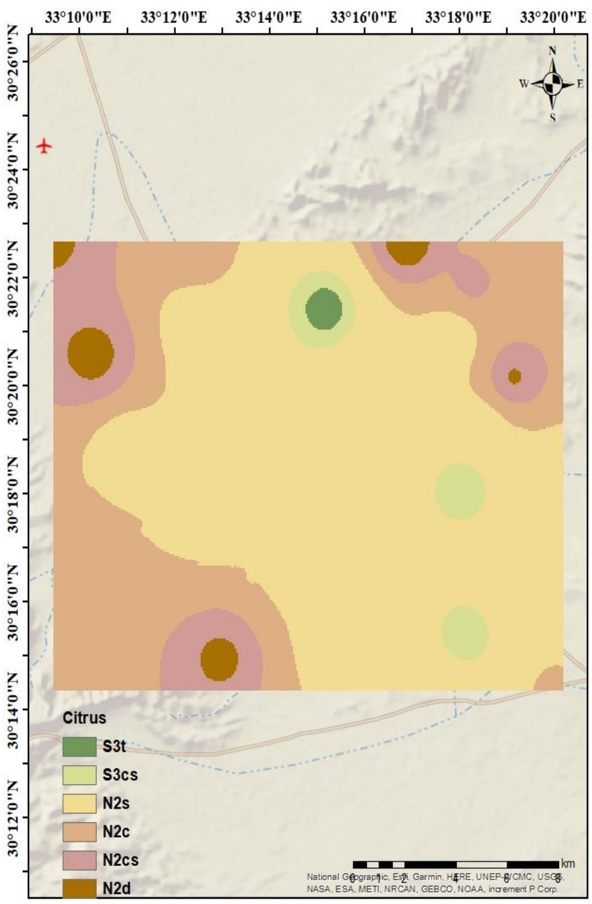

Figure 4. Land suitability for Citrus crops. (Sys, model).

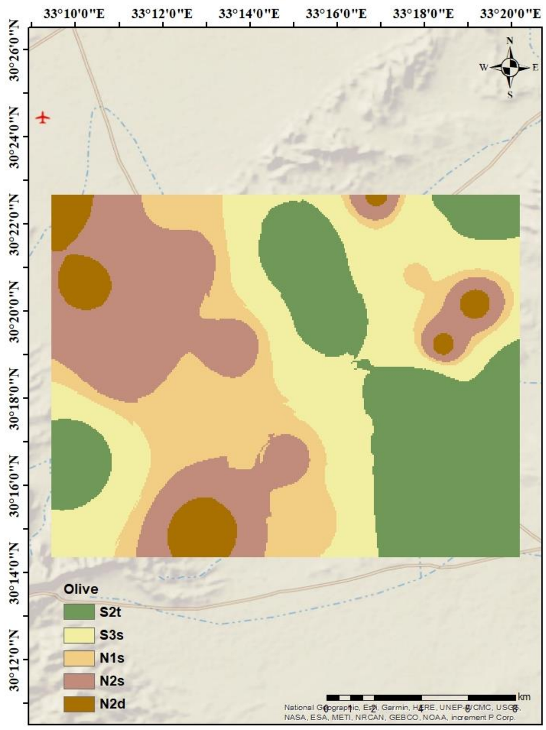

Figure 5. Land suitability for Olive crops. (Sys, model).

Land suitability model (ALMAGRA)

The ALMAGRA soil suitability model is based on the analysis of edaphic factors that affect the productivity of semi-annual and perennial crops. A land suitability assessment was conducted in the study area. Depth, texture, drainage, soil carbonate content, soil salinity, sodium saturation and profile were chosen to be limiting factors in crop development. Three crops (semi-annually and perennial) were selected and assessed based on their needs and the land characteristics of the mapping units. For semi-annual and perennial crops, the main limiting factor for suitability classes is soil texture, calcium carbonate, drainage, soil depth and some soils have very severe limits on salinity. As demonstrated from Figures (6 ,7 and 8), the suitability for the most crops vary from "marginal suitable" to "non-suitable" due to various restricting variables. Consequently, the soils in the study area associated with the type of mapping units are categorized into three appropriate land classes:

Moderately suitable land (S3): In the study area, soil in this class is small in size and could be cultivated with olive, these areas are represented by soil profiles (1, 4, 6, 7 and 8) in a alluvial plain unit. While the land marginally adapted to alluvial terraces unit of mapping is represented by a very small area (profiles Numbers 12 and 15). These soils have moderate severe limits, e.g. textural, salinity, and calcium carbonate levels. Alluvial plain mapping unit has very small area represented by (profiles 4 and 6) are moderately suitable to citrus fruits, the main limitations are detected the soil texture and salinity.

Marginally suitable land (S4): This includes lands with severe limitations that cannot be economically corrected with existing knowledge. From the data shown, it is clear that the soil represents the unit of the alluvial plain which has a lot of soil profiles like (4, 6, 7, 8) which have severe structure limitation for alfalfa crop. Soil salinity and soil texture limitations are repetitive for alfalfa (soil profile 5). Land suitability for olive were marginally suitable for alluvial Terraces (profile 9), the main limitations are useful depth, texture and drainage.

Non-suitable land (S5): The limiting factors of this land are too severe to prevent any prospects for a successful sustainable use of the land. These soils have very severe and severe limitations, for example, soil texture, soil profile depth, calcium carbonate content and salinity.

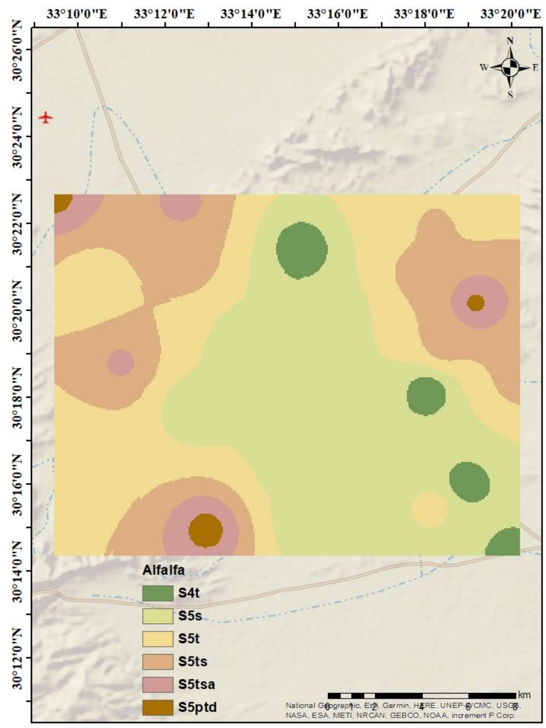

Figure 6. Land suitability for alfalfa, (ALMAGRA model)

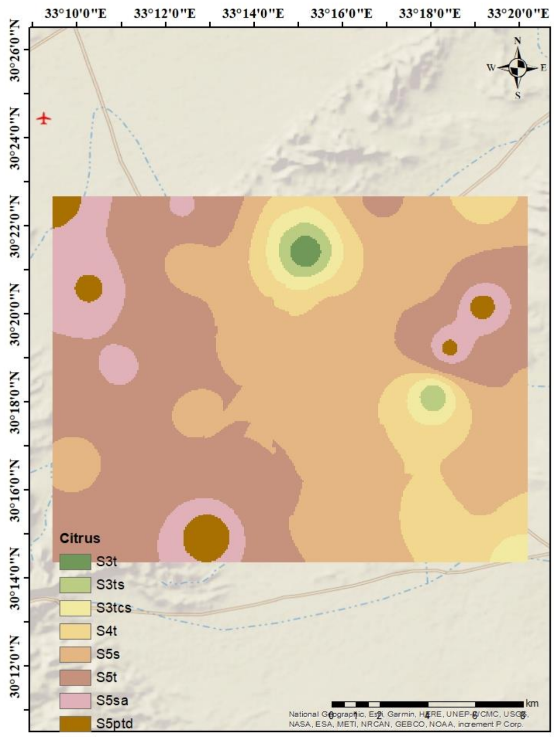

Figure 7. Land suitability for citrus, (ALMAGRA model)

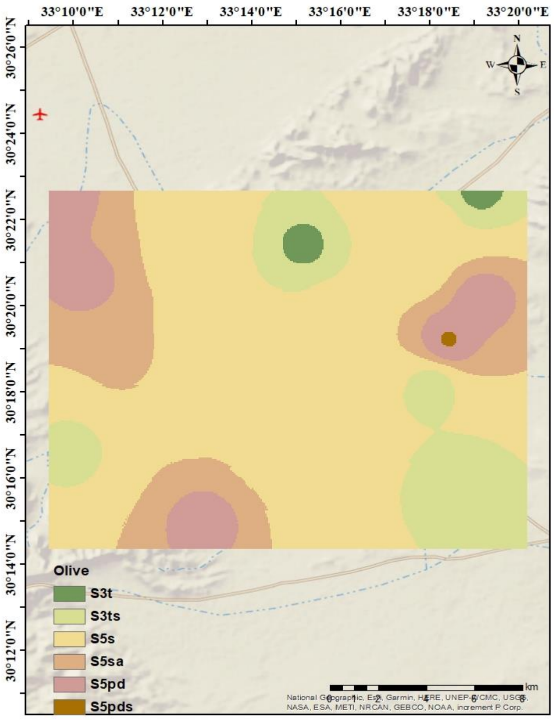

Figure 8. Land suitability for Olive, (ALMAGRA model)

Consulting the land suitability system for certain crops. The Sys model reveals that the study area is marginally suitable (S3) in some soils, and in most cases seemingly not suitable (N1and N2) for a wide range of crops such as forages (alfalfa), fruits (citrus and olive). According to ALMAGRA model the soils under study are grouped into classes moderately suitable land (S3) and not suitable land (S5), respectively. The soils investigated are currently under rain-fed irrigation, and data cleared that the Sys model is more suitable for application than the ALMAGRA model for major crops such as olives, citrus and alfalfa. The results also showed that it is easier to apply modern software-controlled methods such as MicroLEIS than parametric methods.

The land classifications suitable for crops developed by Sys model and the ALMAGRA model have some limitations with regard to soil salinity and soil texture ratings, but they yield acceptable results if the systems are improved. The land suitability models of Sys and ALMAGRA were used to assess the suitability of the land for crops that represent the characteristics of the soil in the study area. Salinity is the main limiting factor and can be easily improved at lower cost with coarse sandy soil texture, intensive irrigation and proper drainage. The suitability of the land for the main suitable crops ranged from moderately suitable to marginal (S2 and S3) and non-suitable (N2 and S5). Olive is the most suitable soil fruit crop and will be amended by crops such as citrus. In addition, forage crops such as alfalfa are moderately suitable or non-suitable. Soil profiles represented as non-suitable (N2 or S5) have an uncorrectable limitation factor or a high correctable cost.

CONCLUSION AND RECOMMENDATION

Egypt is located in an arid to semi-arid region characterized by scarcity of arable land and natural water resources, which puts the livelihoods of its inhabitants at risk. Harvesting of rainwaters is a vital aspect for increasing water and soil productivity as well as coping with climate change in drier marginal environments. Wherefore, a land suitability assessment is important for determining the location and types of rainwater harvesting interventions.

In accordance with the previous lines, it is obvious that the methods and models are different in their categories in terms of suitability of the soil for the same crop which has chosen to grow in the reclaimed soil. This difference can be indicated that the ALMAGRA model is based on soil characteristics such as depth of soil profile, soil drainage, soil texture, soil calcium carbonate content, soil salt content, exchangeable sodium percentage, and soil profile development. Whereas, Sys model is based on previously mentioned soil properties in addition to soil topography, coarse soil fragments, gypsum, cation exchange capacity, and soil organic matter content.

The physical land suitability assessment, implemented and demonstrated in this work, is counted on globally accepted methods for arid and semi-arid soils of the Mediterranean region climate. The land suitability index depends on the value of the selected higher limiting factors. Classification of texture classes for irrigation, suitability shows the lowest values displayed when the investigated soil has a sandy texture. In effect, soils of coarse texture with high salinity are more suitable than those of heavy texture. According to ALMAGRA model, soil electric conductivity level for crops evaluation should not exceed 12.0 dSm-1, while land suitability for crops framework (Sys model) might be less than 32 dSm-1.

These results indicated that the region currently lacks a high suitability for perennial crops, and most land use systems ranged from moderate or marginally suitable classes and/or non-suitable categories. Land suitability for crops according to the Sys model ranged from moderately suitable (S2) to permanently unsuitable (N2). Whereas, the suitability of land for crops according to the ALMAGRA model is moderately suitable (S3), marginally suitable (S4) and non-suitable (S5). The alluvial plain mapping unit has a very small area moderately suitable for citrus, and the main limitations that revealed in the soils were soil texture and soil salinity.

The obtained results showed that Sys *et al* 1993 method has better accuracy than the limitation method and modern approaches for instance; MicroLIES is easier than parametric methods. The land suitability for different crops (MicroLIES model) was implemented in the studying of soils located in the Mediterranean climate regions. Northwest and central Sinai in Egypt is located in the Mediterranean region, so it could be concluded that this method is amenable to precisely study the investigated area.

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تقييم بعض طرق تصنيف ملاءمة التربة لزراعة بعض المحاصيل، وسط سيناء، مصر

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تلعب نظم تقييم التربة دوراً مهماً في التنمية الزراعية المستدامة، كذلك الأنشطة الزراعية والنظم الغذائية المستدامة يجب أن تصبح أكثر فاعلية لتقليل الفجوة بين الإنتاج والاستهلاك. حيث تعتبر شبه جزيرة سيناء مدخل القارة الأسيوية من قارة أفريقيا والعكس، مما يعكس أهمية المنطقة واهتمام الحكومات من خلال الاستراتيجيات لتنمية المنطقة وخاصة استراتيجية التنمية الزراعية. ويهدف هذا البحث إلى معرفة مدى صلاحية الأراضي للاستخدام الزراعي بمنطقة الجفجافة وسط سيناء. بالإضافة إلى مقارنة نظم تصنيف جودة ملائمة التربة لزراعة أهم المحاصيل (باستخدام نظام Sys ونموذج المجرة – ميكروليز) .تقع منطقة الدراسة بين خط عرض ٣٠ ° ١١ 'إلى ٣٠ ° ٢٧' شمالاً وخط طول ٣٣ ° ١٥ إلى ٣٣ ° ٢٤ شرقاً، وتغطي حوالي ٨٠,٠٠٠ فدان. بناءً على التكوين الجيومورفولوجي الذي تم تحقيقه في المنطقة، تشتمل منطقة الدراسة على السهل الغريني، المصاطب الغرينية، رواسب الوادي، والمناطق الصخرية. تم اختيار طرق تقييم تعتمد على مدى ملائمة الأراضي للزراعة في الأراضي الجافة وشبه الجافة (Sys ١٩٩٣) وكذلك أراضي البحر المتوسط (ميكروليز) . من الواضح أن الطرق مختلفة في فئاتها من حيث ملاءمة التربة لنفس المحصول الذي اختار الزراعة في التربة المستصلحة. يمكن الإشارة إلى هذا الاختلاف أن نموذج ALMAGRA يعتمد على خصائص التربة مثل عمق المظهر الجانبي للتربة، والصرف، والملمس، ومحتوى كربونات الكالسيوم، ومحتوى الأملاح، ونسبة الصوديوم القابلة للتبديل، وتطوير ملف التربة، بينما يعتمد نموذج Sys على الخصائص المذكورة سابقًا وإضافة تضاريس التربة وشظايا التربة الخشنة والجبس والقدرة على التبادل الكاتيوني والمواد العضوية.تشير النتائج إلى أن المنطقة حاليًا تفتقر إلى الملاءمة العالية للمحاصيل الدائمة، وتتراوح معظم أنظمة استخدام الأراضي بين فئات مناسبة أو غير مناسبة. تراوحت نتائج ملاءمة الأرض للمحاصيل وفقًا لطريقة (Sys 1993) بين مناسبة إلى حد ما (S2) وغير مناسبة بشكل دائم (N2) . في حين أن ملاءمة الأرض للمحاصيل وفقًا لنموذج (MicrolIES (ALMAGRA مناسبة إلى حد ما (S3) ، ومناسبة هامشيًا (S4) وغير مناسبة (S5) . تحتوي وحدة التربة (السهل الغريني) على مساحة صغيرة جدًا مناسبة بشكل معتدل للحمضيات، وتعتبر المحددات الرئيسية التي تعيق أو تقلل الإنتاج هي قوام التربة والملوحة.