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Soil Maps based on GIS and ALES-Arid Model as Tools for Assessing Land Capability and Suitability in El-Sadat Region of Egypt

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THE SOIL in the El-Sadat region is considered one of the most promising places for land reclamation projects due to its location and the availability of the Nile River and groundwater resources for crop irrigation. This study aimed to create land capacity and suitability maps for certain crops (wheat, sugar beet, maize, peanut, potato, watermelon, olive, citrus and apple) by using ALES-arid program and GIS in the El-Sadat area of Egypt. For this purpose, 14 soil profile were excavated and collected of soil samples. Topographical and geological maps, land cover maps, demarcations, remote sensing images and climatic data were obtained and the main physical and chemical properties of the collected soil samples were analyzed. The gained information were developed through the ALES-arid software to obtain the land capability and suitability maps. Most of these soils were classified as Typic Torripsmments and only profile No. 5 was Typic Torriorthents, with loamy sand dominant texture. There are three geomorphic units (Plain, Elevated area and High Land) prevailing in the study area. According to ALES-arid program, the capability of lands in the studied area was divided into three classes of good (C2), fair (C3) and poor (C4).The occupancy rate for each class of the study area was 5.61, 48.47 and 45.92 % for C2, C3 and C4, respectively. Soil texture, cation exchange capacity, and permeability were the limiting parameters for land capability. The whole results indicated that, about 40.56, 30.96, 21.57 and 6.91 % of the studied area were highly suitable (S1), suitable (S2), moderately suitable (S3) and marginally suitable (S4) for agriculture, respectively. The main of suitability limitations in the studied area were soil texture, permeability and fertility. These limitations are not permanent and can be improved by applying appropriate management practices.

Keywords: GIS, Soil evaluation, Land capability, Land suitability, ALES-arid.

1. Introduction

Land resources in Egypt face great challenges from the lack of agricultural soil and the increase in population (Rashed and Hassan, 2019).The main problem in Egypt, especially during the past three decades, is the very rapid population growth against food production (Abdel-Hamid et al., 2010).Therefore, the conscious management and planning of Egypt's natural resources is essential to ensure food supply and sustainability in agricultural development (Abdel-Rahman, 2016 and Bodaghabadi et al., 2015). Egypt has many promising areas that have not been developed and exploited. El-Sadat region is one of these areas, which is located in the

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southwestern part of the Nile River Delta. Most of its region constitute a very small part of the Western Desert, which is dominated by sandstone formations (Abd El-Kawy et al.,2011, Tewksbury et al., 2012). A small part of the study area is an interference area between the alluvial sediments of the Nile River and sandy deposited (Abd El-Kawy et al.,2011). The surface of the study area is dissected by shallow drainage lines, directed either to the Nile Delta basin or to Wadi El Natrun and Wadi El Farigh depressions (El Abd, 2005 and Salem et al., 2019).

Land evaluation is considered the cornerstone of land use planning for agricultural development (Rashed et al., 2019). The extent to which the land is suitable for a specific use is termed as land suitability (FAO, 2006 and Shyju and Kumaraswamy, 2019). Also, the most commonly term used for evaluating agricultural land is called land capability (FAO, 2007). Land suitability valuation is the process of evaluating land performance to forecasting the potential land for crop production (Pan and Pan, 2011 and Darwish and Abd El-Kawy, 2014), and identifying the main limiting factors for the agricultural production to increase land productivity (Abdel-Rahman et al., 2016). Capability classification is divided into three main classes of soil groups: classes, subclasses and units (FAO, 2007). This system has seven classes of capability. These classes are groups of land units according to their degree of limitations. Restrictions increase gradually from first to seventh class. On the other hand, land suitability classification was proposed by FAO (2006). Two suitability categories are distinguished in this system that are: suitable (S) and unsuitable (N). The first category (S) is subdivided into very suitable (S1), moderately suitable (S2), and marginally suitable (S3). While, the second category (N) is classified into currently unsuitable (N1) and permanently unsuitable (N2).

There are a several of models and systems for conducting land assessment that are used when planning for land use (FAO, 1993). Some of these models are the LECS (Land Evaluation Computer System) and ALES (Automated Land Evaluation System) (Sys et al., 1991). These systems were developed to assess agricultural constraints that affect land capability under prevailing conditions. Using the ALES arid-model in arid and semi-arid regions facilitated the finding of the most suitable agricultural system to be adopted (Abd El-Kawy et al., 2010). Land assessment applied to assess the land capacity and land suitability for a specific use in different conditions, can be performed automatically by using ALES software and GIS technique (Abdellatif et al., 2021 and Gouda et al., 2018).

Remote sensing (RS) images are a powerful tool for studying the Earth's surface and analyzing crop systems (Sadeghi et al., 2015; Aldabaa and Yousif, 2020 and Jalhoum et al., 2022). Geographic Information System (GIS) plays a major role in analyzing the suitability of crop production. These techniques were used to evaluate the criteria required to determine the land suitability (El Baroudy, 2016).RS and GIS have been used in many studies in Egypt for the mapping and management of land resources (Mohamed et al., 2014 and Saleh and Belal, 2014). RS data along with soil survey information can be integrated into a GIS to assess the crop suitability for different soils (Abdel-Rahman et al., 2016).

The main objectives of this study were to: (1) assess land resources of El-Sadat area, (2) evaluate the major land use restrictions and (3) produce the land capability and suitability maps for different crops by using soil physiochemical properties, GIS technology, and ALES program. This is to help in creating a decision-making frameworkand future planning for the studied area.

2. Materials and Methods

Study area

El-Sadat area is located in Menoufia governorate, south western Nile Delta of Egypt. It is bounded to the east and west, respectively, by Cairo-Alexandria desert high away and Rosetta branch of the River Nile, to the north by El-Beheira governorate and to the south by Giza governorate (Figure 1). The study area (53.47 km^2) is situated between latitudes 30°15'50" - 30°34'00" N, and longitudes 30°19'30" - 30°40'27" E. The area lies in semi-arid to arid climate conditions (desert condition).

The mean annual temperature of the studied area is 21.19 °C, with the highest temperature value of 35.74°C in July and the minimum value (7.93 °C) in January. Mean annual precipitation is about 2.0 mm, ranges from 0.3 to 3.5 mm in May and January, respectively. The evaporation rate varies from 4.68 and 13.4 mm/day. It is generally formed of some low-lying hills that received special attention due to their good groundwater resources. The elevations of this area vary between 20 m in the vicinity of the Nile Delta and 70 m above sea level (ASL) near Wadi E1-Natrun (Sharaky et al., 2016).

This area is essentially occupied by sedimentary rocks belonging to the Quaternary Era. These sedimentary rocks included Colluvial deposits, Aeolian deposits, and Nilotic sands and gravels forms (El-Fayoumy, 1989). Embaby (2003) reported that, alluvial and Aeolian deposits are the most distinguished geological units in the study area. Sedimentary rocks belong to the Miocene, Pliocene and Quaternary ages. The area is characterized by gentle and smooth reliefs. Geomorphologically, the Western Nile Delta region is divided into four units; young alluvial plains, old alluvial plains, conglomerates and sand dunes (Dawoud et al., 2005).The investigated area is a part of the alluvial plains, which it characterized by a rolling surface sloping to the north and northeast. It is essentially underlain by dark brown gravel and coarse sand with fragments of fossil woods in the southern portions and sandy deposits in the northern parts (Embaby, 2003).

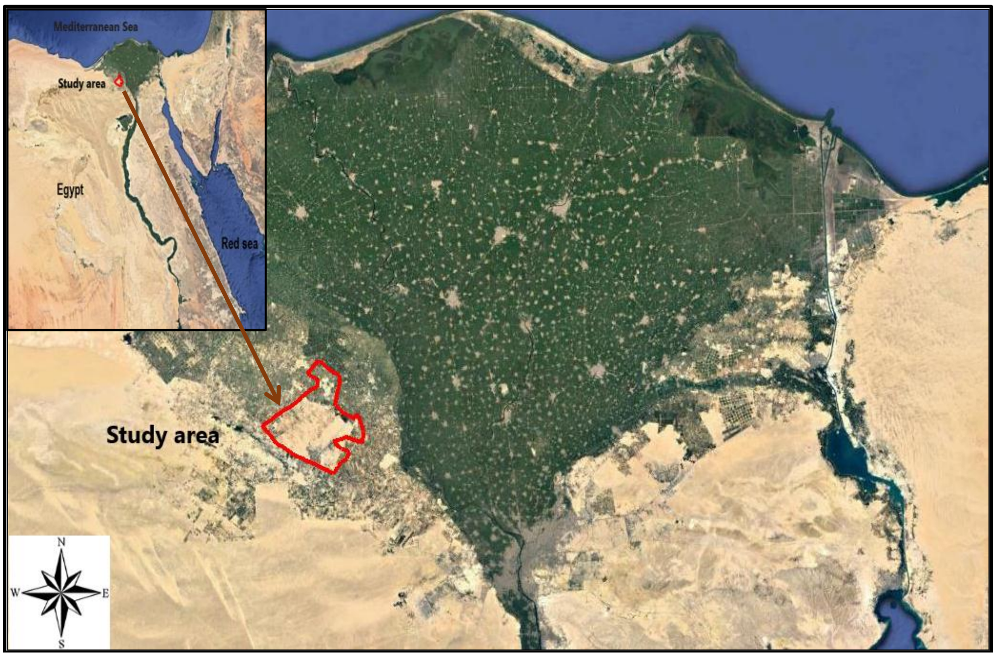

Fig. 1. Location map of the study area

Image processing and the used Software

All free images on the internet are registered to the latitude-longitude coordinate system. This step is carried out using ENVI software version5.0, as an Image- to-image or image-to-map registration. The available ISO Data and K-Means techniques were used. The image was classified into 20 classes, then regrouped according to similarity and closeness into 3 classes representing the main physiographic units in the study area, which are 1) plain, 2), elevated area, and 3) high land (Figure 2). Digital elevation analyses were performed on SRTM data to extract parametric information of slope and aspect, (Wood, 1996) using ArcMap software 10.1 (ESRI, 2014). Slope was extracted as a percent from the corrected DEM using the slope tool in ArcMap 10.1. Aspect is defined as the direction that the slope faces.

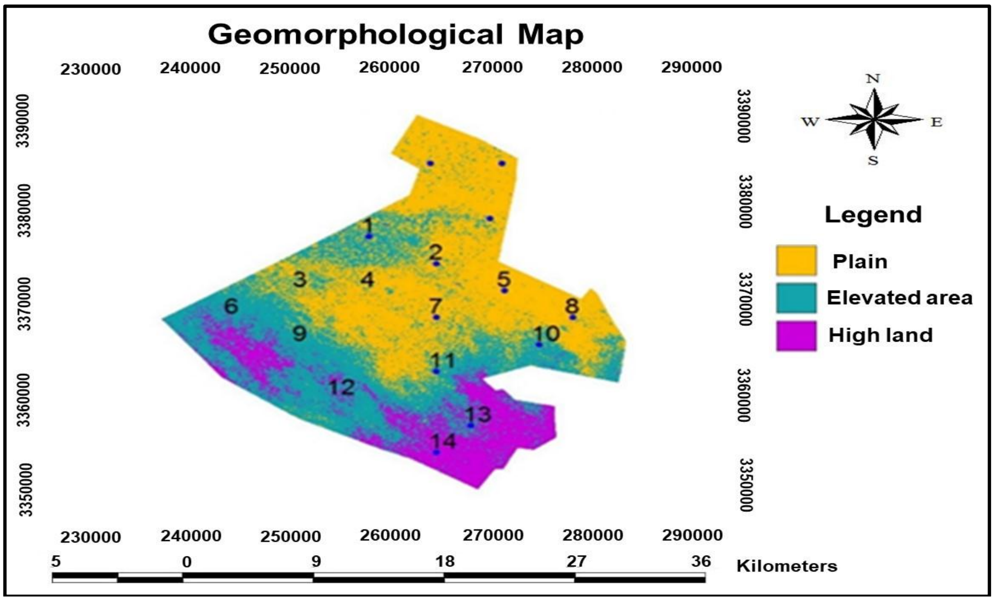

Fig. 2. Geomorphic map unites and locations of studied soil profile

Field work

Fourteen soil profiles were selected to represent the identified physiographic units (Figure 2). The GPS device (Garmin eTrex 10) was used to define the latitudes and longitudes of the soil profiles. The soil profiles were dug down to 120 cm and they were morphologically described on the basis outlined by FAO (2006).Based on the vertical variations of horizons,a total of 57 soil samples representing different soil layers of the studied profiles were collected and stored for laboratory analysis.

Laboratory analysis

The collected soil samples were air-dried, crushed softly, and passed through a 2-mm sieve to get the fine soil part.The fine soil was analysed in the laboratory for physicochemical and fertility characteristics analyses. Gravels content, particle size distribution, pH, electrical conductivity (EC), soluble cations and anions, organic matter (OM), calcium carbonate ($CaCO_3$), gypsum, cation exchange capacity (CEC), exchangeable sodium percentage (ESP), and available N, P, K were determined according to Sparks et al. (2020) and Burt (2014). The soil hydraulic conductivity was determined at saturation under a constant head (Klute and Dirksen, 1986).

Land Evaluation

Evaluation of land capability and suitability was carried out using the Agriculture Land EvaluationSystem for arid and semi-arid regions (ALES-arid). The ALES capability model forecasts the general land use capability for a broad series of possible agricultural uses (Figure 3). This model is integrated with the ArcGIS software package to calculate the final soil capability index and suitability classes for specific crops (Ismail et al., 2001). It depends on three main factors: soil physical and chemical properties, soil fertility parameters, and irrigation water quality. The ALES capability model predicts the general land use capability for a wide range of potential agricultural uses.

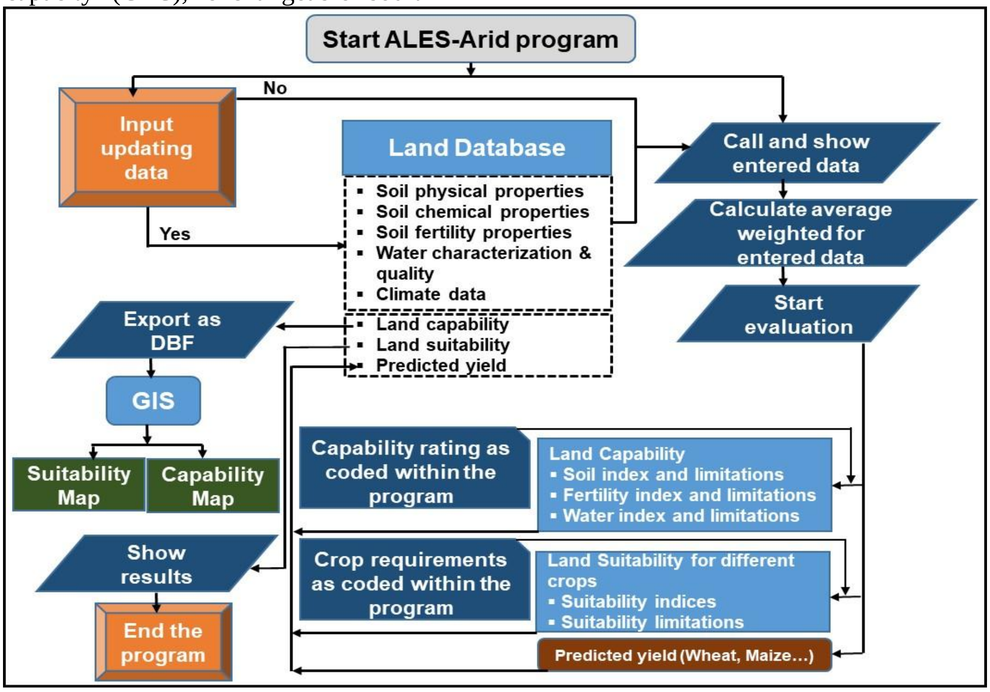

Fig. 3. Flowchart of the ALES-Arid program model

The methodological criteria refer to the system designed by Ismail et al. (2001) and the FAO framework for land evaluation (FAO, 1977).The capability evaluation includes six capability orders for reclamation and agriculture land capability (Table 1).Soil depth, texture, $CaCO_3$, gypsum content, EC, ESP, drainage, and slope were feed into the ALES-arid model under the Arc GIS 10.1 software to derive land capability and suitability. Evaluation of land suitability was applied based on the rating of crop requirements proposed by Sys et al. (1993) and the ALES suitability model (Ismail et al., 2001). The ALES is a soil suitability assessment model that indicates the degree of suitability for land use. It includes six suitability classes for each crop (Table 1). The factors affecting the land suitability for a specific crop are the physical properties of clay content, profile depth, land forms, surface level and slope that determine the soil and water relationship. The chemical properties of pH, $CaCO_3$, gypsum, CEC, ESP, and EC determine the fertility of soil. Nine crops (wheat, sugar beet, maize, peanut, potato, watermelon, olive, citrus, and apple) were selected to assess their suitability to be grown in the studied area includes six suitability classes for each crop (Table 1). The factors affecting the land suitability for a specific crop are the physical properties of clay content, profile depth, land forms, surface level and slope that determine the soil and water relationship. The chemical properties of pH, $CaCO_3$, gypsum, CEC, ESP, and EC determine the fertility of soil. Nine crops (wheat, sugar beet, maize, peanut, potato, watermelon, olive, citrus, and apple) were selected to assess their suitability to be grown in the studied area.

TABLE 1. Land capability and suitability index classes and ratings using ALES program

Class	Description	Rating (%)	Class	Description	Rating (%)
C1	Excellent	80 - 100	S1	Highly suitable	80 - 100
C2	Good	60 - 80	S2	Suitable	60 - 80
C3	Fair	40 - 60	S3	Moderately suitable	40 - 60
C4	Poor	20 - 40	S4	Marginally suitable	20 - 40
C5	Very poor	10 – 20	NS1	Currently not suitable	10 – 20
C6	Non-agriculture	< 10	NS2	Permanently not suitable	< 10

3. Results and Discussion

Land surface analysis

Digital image processing of ETM+ image indicated that there are 3 main geomorphic units prevailing in the study area (Table 2, Figure 2). These three geomorphic units (from the east to the west) are Plain, Elevated area and High land. The area of Plain landscape is about 2411.46 ha (43.44 % of the total area) and represented by 5 soil profiles (2, 4, 5, 7, and 8). Elevated area is located between Plain and High land forms in the study area (1802.03 ha, 32.46 %) and represented by 6 soil profiles (1, 3, 6, 9, 10, and 11). Towards the west of the study area, High land landscape represents the smallest area of about 1337.48 ha (24.1 % of the total area), where it was represented by 3 soil profiles (12, 13, and 14). The morphological features of the studied profiles indicated that, the parent material of all soils in the study area belong mainly to sandstone. Topography is almost flat to gently undulating with different elevation ranging from 14 to 40 m above sea level (ASL) in the Plain area, from 27 to 56 m ASL in the Elevated area, and from 36 to 52 m ASL in the High Land area.

Digital Elevation Model (DEM) was extracted from Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER). Digital elevation analyses were performed on ASTER_DEM data (Figure 4) to extract parametric information, including slope, (Wood, 1996) and aspect using ArcMap software 10.1(ESRI, 2014).

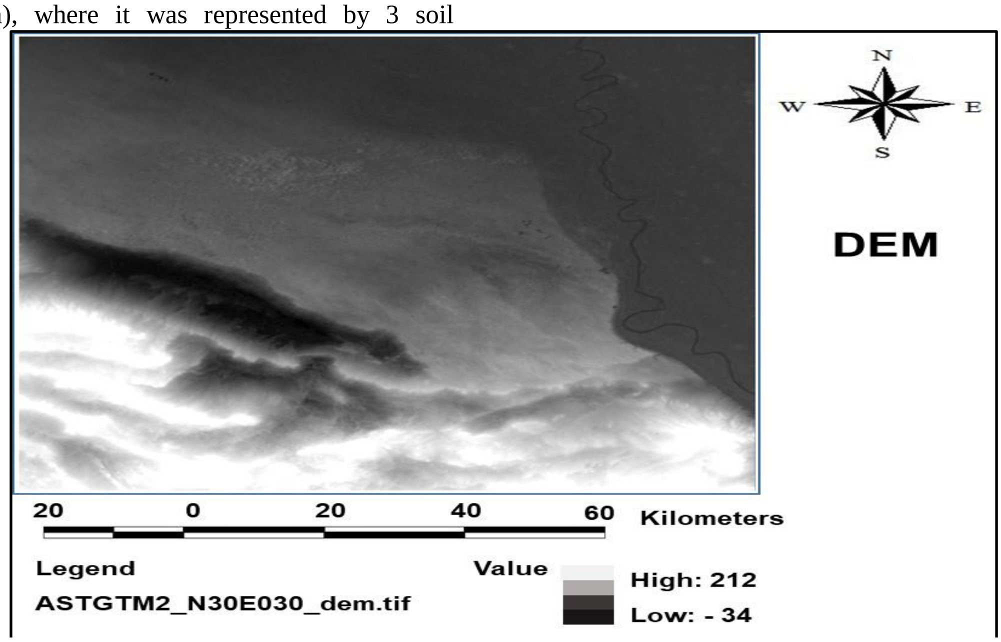

Fig. 4. Digital elevation model (DEM) of the study area.

TABLE 2. Area of each geomorphic unit and its percentage from the total study area.

Geomorphic units	Area			
	Profile numbers	Km^2	Hectare	%
Plain	2, 4, 5, 7, 8	23.23	2411.46	43.44
Elevated area	1, 3, 6, 9, 10, 11	17.36	1802.03	32.46
High land	12, 13, 14	12.88	1337.48	24.1
Total		53.47	5550.98	100

Elevation varies between -34 m and 212 m above sea level (Figure 4).Slope was extracted from the corrected DEM to the producing the land form structure of the study area. The slope gradient of the studied area was classified into seven classes according toFAO (2006),where it varied from flat to strongly sloping (Figure 5). The aspect (slope faces or directions) in the study area was derived from the DEM. The slope aspect varied from 22.5 to 360 (north), and from 159.5 to 202.5 (south). Figure 6 shows the aspect analysis of the studied area.

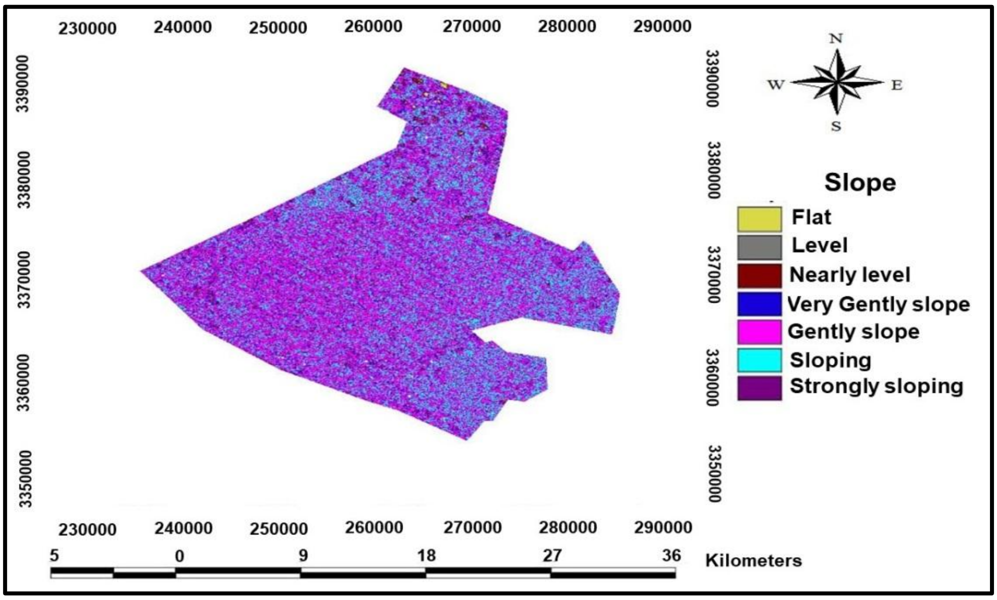

Fig. 5. Slope gradient classes of the studied area

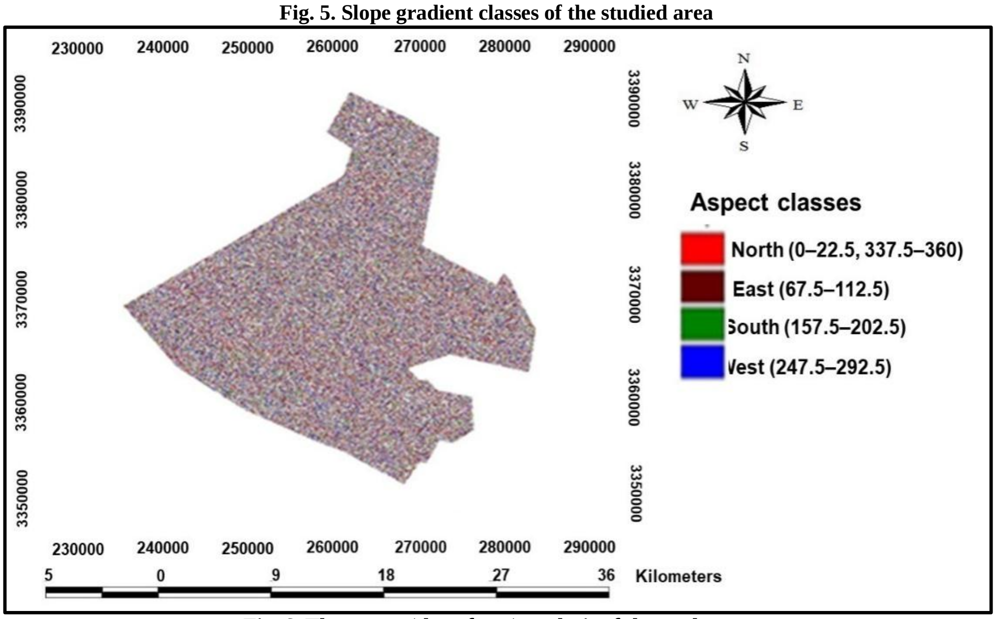

Fig. 6. The aspect (slope faces) analysis of the study are.

Soil physical and chemical properties

The analytical data of the studied profiles are presented as weighted profiles means (WPM) which are shown in Table 3. The soils are slightly gravelly (<15%) in profiles (1, 2, 3, 4, 5, 6, 7, 11) which gravels ranged between 2.8 and 14.2 %. It was gravelly (>15 %) in profile (8, 9, 10, 12, 13, 14) and the gravels varied from 15.5 to 28.5 % (Ismail et al., 2005). Sand grains varied from 81.7 to 85.9 %, silt ranged between 3.8 and 7.8 %, and clay particles varied from 9.6 to 12.0 %. All of the examined soil samples were classified according to the texture grade as loamy sand.Soil hydraulic conductivity (HC) was rapid and ranged between 32.7 and 188.5 cmh^{-1}. These high values reflect serious need for irrigation and drainage practices management (Bhardwaj et al., 2007). Soil pH ranged between 7.2 and 7.8, which indicates the soils are slightly alkaline (Dinkins and Jones, 2013). The electrical conductivity (EC) values varied from 0.2 to 2.9 dSm^{-1}, indicating low soluble salt content and low salinity level (0-2 dSm^{-1}). Except for profile No. 9 (2.9 dSm^{-1}), which could be considered moderately saline soil (2-4 dSm^{-1}), according to Hazelton and Murphy (2016) classification. Also, Data in Table 3 show that, Cation exchange capacity (CEC) was very low (<6.0 $cmolkg^{-1}$) and varied from 2.0 to 5.3 $cmolkg^{-1}$. This could be attributed to the low content of fine fractions and organic matter in these soils (Caravaca et al., 1999). Exchangeable sodium percentage (ESP) ranged between 0.4 and 3.4 %, indicating no sodicity effect on these soils (Chhabra, 2004).

Total carbonate ($CaCO_3$) content varied widelybetween 3.0 and 27.1 %. $CaCO_3$ content of these soils could be attributed to the calcareous nature of the original bedrock (Taalab et al., 2019). This calcareous nature may negatively affect the physical properties and inhibits the availability of soil nutrients (Wahba et al., 2019 and Shokr et al., 2022). Gypsum content was generally very low and ranged between 0.02 and 0.46 %. Soils were poor in their content of organic matter (OM)and it ranged between 0.17 and 0.60 %, which could be due to the prevailing arid conditions (Oyonarte et al., 2007).

TABLE 3. Physical and chemical properties of the studied soil profiles in El-Sadat region.

Geomorphic units	Profile No.	Gravels (%)	Particle size distribution (%)			Texture class	HC ($cm\ h^{-1}$)	pH	EC (dSm^{-1})	CEC ($cmol\ kg^{-1}$)	ESP (%)	$CaCO_3$ (%)	Gypsum (%)	OM (%)
			Sand	Silt	Clay									
Plain	2	3.6	83.6	4.4	12.0	L sand	86.8	7.5	0.8	4.2	0.7	3.0	0.22	0.41
	4	2.8	84.2	3.8	12.0	L sand	150.1	7.5	1.8	5.0	3.4	4.4	0.03	0.54
	5	7.6	83.0	5.0	12.0	L sand	109.5	7.5	0.2	5.1	0.4	5.1	0.02	0.23
	7	7.5	83.1	6.5	10.4	L sand	65.1	7.3	1.5	3.8	3.2	6.2	0.25	0.35
	8	19.1	83.7	4.6	11.7	L sand	80.6	7.8	0.3	5.3	0.8	7.7	0.03	0.35
Elevated area	1	8.4	85.5	3.8	10.7	L sand	159.1	7.6	0.2	0.4	3.3	13.7	0.04	0.20
	3	12.1	83.6	4.4	12.0	L sand	188.5	7.2	0.9	4.1	0.6	5.0	0.33	0.60
	6	14.2	83.2	5.8	11.0	L sand	98.6	7.6	1.3	3.8	1.4	10.1	0.21	0.55
	9	24.1	81.7	7.8	10.5	L sand	89.1	7.2	2.9	3.5	3.4	27.1	0.20	0.13
	10	17.9	82.6	7.6	9.8	L sand	69.4	7.7	0.2	5.2	0.4	8.9	0.04	0.21
	11	14.2	85.9	4.5	9.6	L sand	92.8	7.4	0.9	2.9	1.5	10.8	0.08	0.18
High land	12	28.5	84.8	4.4	10.8	L sand	32.7	7.7	0.2	4.8	1.0	18.7	0.02	0.23
	13	20.2	82.9	5.7	11.4	L sand	85.1	7.5	1.9	2.0	1.2	17.3	0.46	0.20
	14	15.5	85.0	3.8	11.2	L sand	170.8	7.7	2.0	4.7	3.2	19.9	0.20	0.17

HC= hydraulic conductivity, **EC**= Electrical conductivity, **CEC**= Cation exchange capacity, **ESP**= Exchangeable sodium percentage, **OM**= organic matter, Values are presented as weighted profiles means (WPM)

Soil fertility of the study area

Available macronutrients are considered indicators of soil fertility. The amounts of available macronutrients fertility status of the soils, and reflect the kind of management given to the soil (Ismail et al., 2005 and Sağlam and Dengiz, 2014). The available contents of N, P and K in the surface layers of the studied soil profiles belonging to the different geomorphic units are given in Table 4. Data indicated that, the available N, P and K contents, in the soils of elevated area are relatively higher than those of other units. These results were authenticated by available N values that ranged from 7.25 to 49.02, from 17.50 to 74.05, and from 11.27 to 77.50 mgkg^{-1} for soils of Plain, Elevated area and High land units respectively. Available P content ranged from 9.02 to 11.05, from 9.31 to 12.01 and from 8.21 to 10.50 mgkg^{-1} for soils of plain, elevated area and high land units respectively. Available K values ranged from 40.25 to 100.12, from 90.22 to 100.90 and from 70.94 to 90.78 mgkg^{-1} for soils of Plain, Elevated area and High Land units respectively.

TABLE 4. Available N, P and K contents in the surface layers of soil profiles represented the studied geomorphic units

Geomorphic units	Profile No.	Available macronutrients (mgkg^{-1})		
		N	P	K
Plain	**2**	7.25	9.02	100.12
	4	35.42	8.01	40.35
	5	42.35	10.12	100.01
	7	11.16	11.05	40.25
	8	49.02	9.02	100.03
Elevated area	**1**	59.50	10.00	100.10
	3	17.50	12.01	100.90
	6	35.24	10.10	90.65
	9	66.50	10.01	100.01
	10	74.05	12.01	90.22
	11	42.17	9.31	100.00
High land	**12**	11.27	10.50	70.94
	13	17.50	10.01	90.67
	14	77.50	8.21	90.78

Land Evaluation using ALES-Arid software

Land evaluation was assessed by using the Agriculture Land Evaluation System (ALES-Arid) software. Land database such as soil physical, chemical, and fertility properties, water characteristics and quality, and climate data were used in this program.

Land capability evaluation

The resulting land capability map (Figure 7**)** shows that, about 5.61% of the area is good (C2), 48.47 % of the study area belongs to class 3 (C3, Fair), and 45.92% of the area is poor (C4). According to ASLE-arid (Ismail et al., 2001), the studied area was classified into three land capability classes:

1) **C2 class (good)**: This class is represented by only small area that located at the northeastern and southeastern edges of the study area, which wasn't represented by any soil profiles (only auger surface samples, Data not recorded).
2) **C3 class (fair)**: This class included most of the studied soil profiles, these profiles are 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, and 14 (Table 5). Soils in this class have limitations that required to be improved such as soil texture and cation exchange capacity. Soil fertility of this class were also low (soil fertility index varied from 20.17 to 37.04 %). This could be due to the lower content of soil OM, available N, P, and K. However, there are no permanent restrictions on all of these classes, so the current capability of these soils can be changed to become (good, C2) with executively intensive management practices (Elnaggar, 2017 and Jalhoum et al., 2022).
3) **C4 class (poor):** This class included soil profiles No. 7, 9, and 12 (Table 5). The soil profiles have some limitations such as texture, available water, CEC, and hydraulic conductivity. It has low fertility index, which ranged between 16.7 and 33.96 %. However, the limitations in these soil are not permanent.Nevertheless, with good management techniques, the soil in this class may be improved to become (fair, C3 or good, C2).

Generally, it is obvious that the main reason for these low levels of land capability is the very low values of the soil fertility index, which didn't reach 40 % for any of the investigated soil profiles (Table 5).The very poor soil fertility is not surprising given that most of the study area consists of uncultivated land. The main land capability limiting parameters are loamy sand soil texture, lack of available water, high soil permeability, low organic matter content, and lack of available N, P and K (Abd El-kawy et al., 2010 and Elnaggar, 2017).

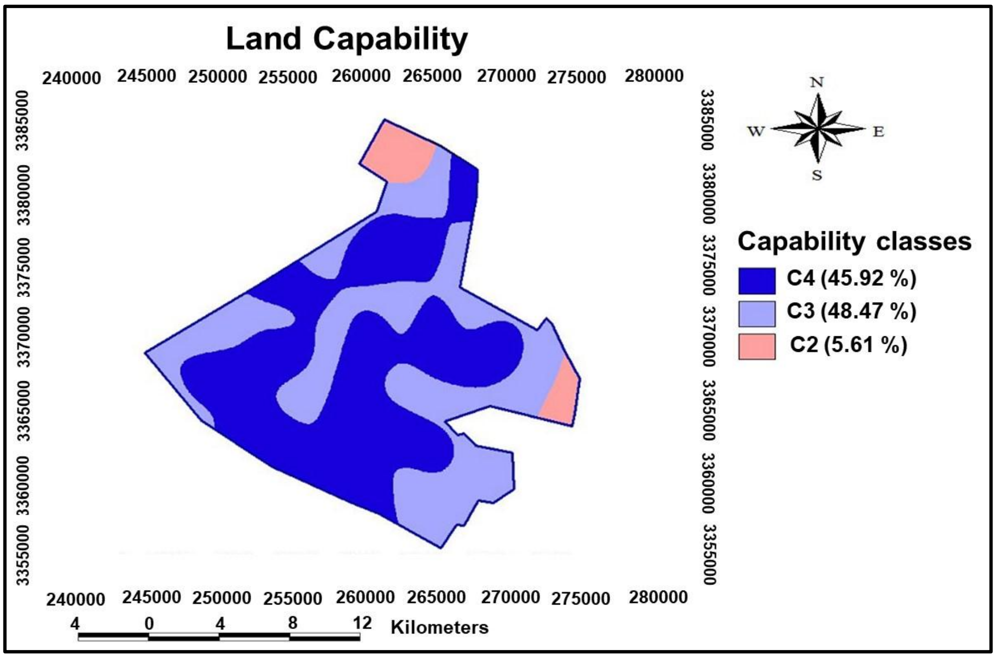

Fig. 7. The spatial distribution for land capability classes in the studied soils

TABLE 5. Land capability classes, indices, and limitations of the investigated profiles

Profile No.	Soil classes & (limitations)	Soil index (%)	Fertility classes & (limitations)	Fertility index (%)
1	C3 (T, CEC)	41.96	C4 (OM, N, P, K)	28.81
2	C3 (T, CEC)	43.44	C4 (OM, N, P, K)	20.17
3	C3 (T, CEC)	42.07	C4 (OM, N)	35.05
4	C3 (T, CEC)	41.89	C4 (OM, N, P, K)	26.39
5	C3 (T, CEC)	42.12	C4 (OM, N, K)	28.42
6	C3 (T, CEC)	40.54	C4 (OM, N, P, K)	27.91
7	C4 (T, CEC)	39.98	C4 (OM, N, K)	21.80
8	C3 (T, CEC)	43.71	C4 (OM, N, P, K)	27.52
9	C4 (T, AW, CEC)	39.00	C4 (OM, N, P)	33.96
10	C3 (T, CEC)	40.79	C3 (OM, N)	٣7.04
11	C3 (T, CEC)	40.05	C4 (OM, N, P, K)	30.48
12	C4 (T, HC, CEC)	39.30	C5 (OM, N, P, K)	16.70
13	C3 (T, CEC)	40.86	C4 (OM, N, P)	29.43
14	C3 (T, CEC)	41.98	C4 (OM, N, P, K)	25.67

C3= fair, **C4**= poor, **C5**= very poor, **T**= soil texture, **CEC**= cation exchange capacity, **AW**= available water, **HC**= soil hydraulic conductivity, **OM** = organic matter, **N**=available nitrogen, **P**= available phosphorus, **K**= available potassium

Land suitability evaluation

Different land suitability classes and indices for several crops were predicted based on the matching between land qualities and characteristics and standard crop requirements using ALES-Arid program (Mahmoud et al., 2020). The land suitability for nine crops of wheat, maize, sugar beet, peanut, potato, watermelon, olive, citrus, and apple were predicted (Figure 8, 9). The results of the ALES program were linked to the GIS modeling to obtain the final maps of land suitability for each crop in the study area. The suitability indicesfor these crops are presented in Table 6, and the spatial distribution for each crop is presented in Figures 8 and 9. The results indicated that, most of the investigated profiles were highly suitable (S1) to moderately suitable (S3) for wheat, sugar beet, peanut, potato, watermelon and citrus. Most of the area was highly suitable (S1) to marginally suitable (S4) for maize, with the dominant S2 class. Also, the studied area was moderately suitable (S2) to conditionally suitable (S4) for apple.

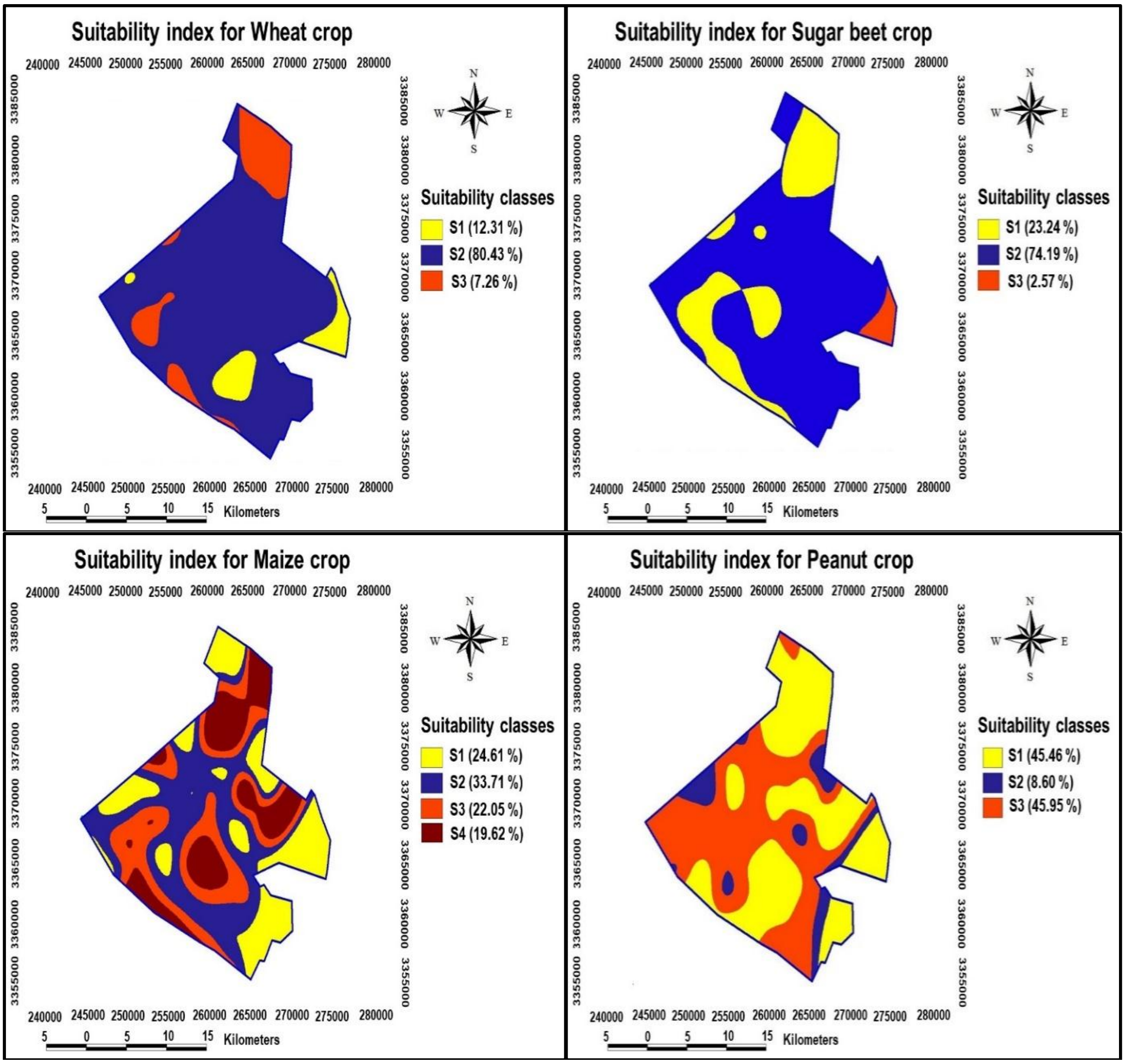

Fig. 8. Land suitability map of wheat, sugar beet, maize, and peanut crops in the studied area
(S1= high suitable, S2= suitable, S3= moderately Suitable, S4= marginally suitable).

The studied area varied from highly suitable (S1) and suitable (S2) for olive trees. The whole results indicated that, 90.0, 88.6, and 52.43% of the studied area was highly suitable (S1) for citrus, olive and watermelon, respectively. Also, about 80.43, 74.19, and 33.71 % of the investigated area was suitable (S2) for wheat, sugar beet and maize, respectively. However, the third category (S3) appeared with the higher values of potato (64.10 %) and peanut (54.94 %) crops in the study area.The main of suitability limitations in the studied area were soil texture, permeability and fertility (Abd El-kawy et al., 2010andElnaggar, 2017).

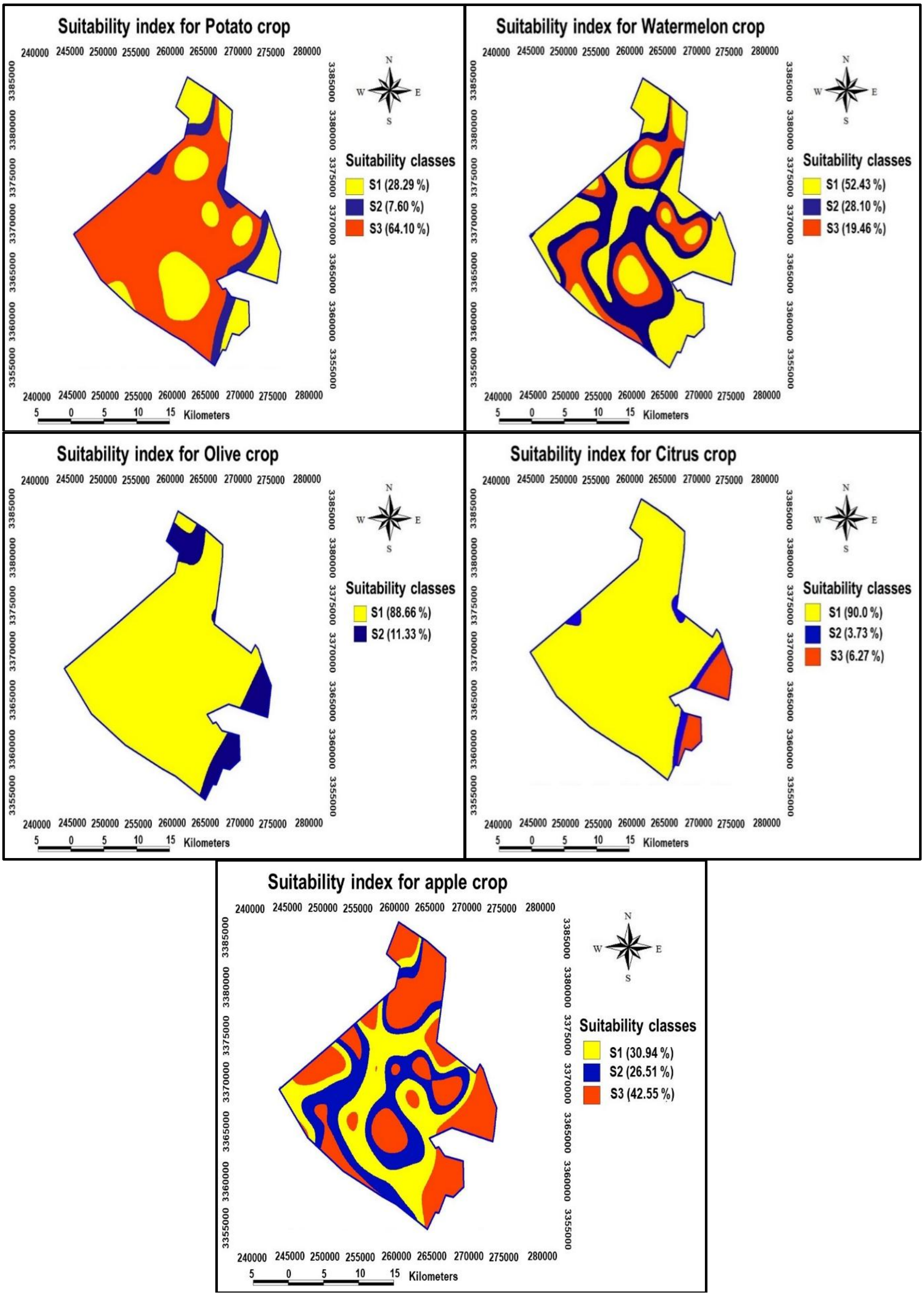

Fig. 9. Land suitability map of potato, watermelon, olive, citrus and apple crops in the studied area
(S1= high suitable, S2= suitable, S3= moderately Suitable, S4= marginally suitable)

TABLE 6. Soil suitability classes and percentage for growing of selected crops in El-Sadat area

Suitability class	Field crops				Vegetables		Fruit trees		
	Wheat	Sugar beet	Maize	Peanut	Potato	Watermelon	Olive	Citrus	Apple
S1	12.31	23.24	24.61	45.46	28.29	52.43	88.66	90.00	0.00
S2	80.43	74.19	33.71	8.60	7.60	28.10	11.33	3.73	30.94
S3	7.26	2.57	22.05	45.94	64.10	19.46	0.00	6.27	26.51
S4	0.00	0.00	19.62	0.00	0.00	0.00	0.00	0.00	42.55

4. Conclusion

Land suitability evaluation can help in achieving the sustainable crop production for agricultural development in the El-Sadat region. ALES-arid model and Geographic Information System (GIS) were more effective in assessing land capability and suitability in arid and semi-arid regions. The aim of this study was to evaluate the soil capability and suitability of El-Sadat area for crop production and identify the reasons that prevent the agriculture progression.

Most of studied soils were classifiedinto two capability classes, C3 (fair) and C4 (poor) accordingto the results of ALES-Arid program. The predominant limiting factors of soil capability

weresoil texture, cation exchange capacity, hydraulic conductivity andfertility. However, these limitations can be improved through appropriate management practices.According to the ALES program, the soils of the studied area varied in the suitability index from high suitability (S1) to marginal suitability (S4).The obtained results play a fundamental role in determining the most suitable crops in the study area.Land evaluation assists decision makers in the sustainable management of agricultural resources. The obtained results play a major role in revealing the most suitable crops in the study area and help decision makers in the management of agricultural resources.

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6. Conflicts of interest

There is no conflict of interest between the authors or any donor or funding agency.

7. References

Abd El-Kawy ORA, Ismail HA, Rod JK, Suliman AS (2010). A developed GIS-based land evaluation model for agricultural land suitability assessments in arid and semi arid regions. *Research Journal of Agriculture and Biological Sciences*, **6**(5), 589-599.

Abd El-Kawy OR, Rod JK, Ismail HA, Suliman AS (2011). Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. *Applied geography*, **31**(2), 483-494.

Abdel-Hamid MA, Ismail M, Nasr YA, Kotb Y (2010). Assessment of Soils of Wadi El-Natrun Area, Egypt Using Remote Sensing and GIS Techniques. *Journal of American Science*, **10** (6), 195 -206.

Abdellatif AD (2021). Assessment of land suitability for surface and drip irrigation systems in the northwestern coast of Egypt. *Egyptian Journal of Soil Science*, **61**(1), 129-140.

Abdel-Rahman MA, Natarajan A, Hegde R (2016). Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. *Egypt. J. Rem. Sens. Space Sci.*, **19**, 125-141.

Aldabaa A, Yousif, IAH (2020). Geostatistical approach for land suitability assessment of some desert soils. Egyptian Journal of Soil Science, **60**(3), 195-209.

Bhardwaj AK, Shainberg I, Goldstein D, Warrington DN, Levy, JG (2007). Water retention and hydraulic conductivity of cross- linked polyacrylamides in sandy soils. *Soil Science Society of America Journal*, **71**(2), 406-412.

Bodaghabadi BM, Martinez-Casasnovas JA, Khalili P, Masihadadi M (2015). Assessment of the FAO traditional land evaluation methods, Acase study: Iranian land classification method. *Soil and Use Management*, **31**, 384 – 396.

Burt R (2014). Soil Survey Staff. Soil Survey Laboratory Methods Manual. Soil Survey

Investigations Report 42, Version 5.0. *US Department of Agriculture, Natural Resources Conservation Service*.

Caravaca F, Lax A, Albaladejo J (1999). Organic matter, nutrient contents and cation exchange capacity in fine fractions from semiarid calcareous soils. *Geoderma*, **93**(3-4), 161-176.

Chhabra R (2004). Classification of salt-affected soils. *Arid Land Research and Management*, **19**(1), 61-79.

Darwish KM, Abd El-Kawy WA (2014). Land suitability decision support for assessing land use changes in areas west of Nile Delta, Egypt. *Arabian Journal of Geosciences*, **7**(3), 865-875.

Dawoud MA, Darwish MM, El-Kady MM (2005). GIS-based groundwater management model for Western Nile Delta. *Water Resources Management*, **19**(5), 585-604.

Dinkins CP, Jones C (2013). Interpretation of soil test reports for agriculture. MT200702AG, Montana State University Extension: Bozeman, MT, USA.

El Abd EA (2005). The Geological impact on the water bearing formations in the area south west Nile Delta, Egypt. *Unpublished PhD thesis, Fac. Sci., Menufiya Univ., Egypt*.

El Baroudy AA (2016). Mapping and evaluating land suitability using a GIS-based model. *Catena*, *140*, 96-104.

El-Fayoumy ME (1989). New approach of land evaluation of some Egyptian regions (Doctoral dissertation, Ph. D. thesis, Fac. of Agric., Alex. Univ).

Elnaggar AA (2017). Development of land capability and suitability maps for Bahariya Oasis, Egypt. *Egyptian Journal of Soil Science*, **57**(4), 489-503.

Embaby AAA (2003). Environmental evaluation for geomorphological situation in relation to the water and soil resources of the region north of the Sadat City, west Nile Delta, Egypt. *Unpublished Ph. D. Thesis, Fac Sci Mansoura Univ. Egypt*, *323*, 60.

ESRI "Environmental Systems ResearchInstitute" (2014) Arc Map Version 10.1User Manual. ESRI, 380 New YorkStreet, Redlands, California, 92373-8100, USA.

FAO (1977). A Framework for Land Evaluation. Institute for Land Reclamation and Improvement/ILRI. Publication 22, Wageningen, the Netherland, 87 pp.

FAO (1993). Guidelines for land-use planning. Development Series I, Rome.

FAO (2006). Guidelines for soil description. 4th Ed. FAO Rome, Italy.

FAO (2007). Land Evaluation, Towards a Revised Framework. Land and water discussion paper No. 6, Rome, Italy.

Gouda MS, El-Baroudy AA, Ibrahim MM, Mohamed ES (2018). GIS-based for land evaluation in some areas at West of Nile Delta. *Zagazig Journal of Agricultural Research*, **45**(4), 1309-1319.

Hazelton P, Murphy B (2016). Interpreting soil test results*: What do all the numbers mean*?. CSIRO publishing.

Ismail HA, Bahnassy MH, Abd El-kawy ORA (2005). Integrating GIS and modeling for agricultural land suitability evaluation at East Wadi El-Natrun, Egypt. *Egyptian Journal of Soil Science*, **45**(3), 297-322.

Ismail HA, Morsy IM, El-Zahaby EM, El-Nagar FS (2001). A Developed Expert System for land use planning by coupling Land Information System (LIS) and Modeling. *Alexandria Journal of Agricultural Research*, **46**(3), 141-154.

Jalhoum MES, Hassan MAER, Farag FM, Abdou M, Abd Elsattar E, Emam M, Shokr M (2022). Modeling of agro-ecological zones for sustainable agriculture development in Halayeb area, Egypt. Egyptian Journal of Soil Science, **62**(1), 55-71.

Klute A, Dirksen C (1986). Hydraulic conductivity and diffusivity: Laboratory methods. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods*, **5**, 687-734.

Mahmoud H, Binmiskeen A, Saad Moghanm F (2020). Land evaluation for crop production in the Banger El-Sokkar Region of Egypt using a geographic information system and ALES-arid Model. Egyptian Journal of Soil Science, **60**(2), 129-143.

Mohamed ES, Saleh AM, Belal AA (2014). Sustainability indicators for agricultural land use based on GIS spatial modeling in North of Sinai-Egypt. *The Egyptian Journal of Remote Sensing and Space Science*, **17**(1), 1-15.

Oyonarte C, Mingorance MD, Durante P, Piñero G, Barahona E (2007). Indicators of change in the organic matter in arid soils. *Science of the Total Environment*, **38**(1-2), 133-137.

Pan G, Pan J (2011). Research in crop land suitability analysis based on GIS. In *International Conference on Computer and Computing Technologies in Agriculture* (pp. 314-325). Springer, Berlin, Heidelberg.

Rashed HS, Hassan FO (2019). Evaluation of land capability and suitability crop production: Case study in Halaib and Shalatien Region, South East Desert of Egypt. *Journal of Soil Sciences and Agricultural Engineering*, **10**(12), 759-769.

Sadeghi M, Jones SB, Philpot WD (2015). A linear physically-based model for remote sensing of soil moisture using short wave infrared bands. *Remote Sensing of Environment*, **164**, 66-76.

Sağlam M, Dengiz O (2014). Distribution and evaluation of soil fertility based on Geostatistical approach in Bafra Deltaic Plain. *Türkiye Tarımsal Araştırmalar Dergisi*, **1**(2), 186-195.

Saleh A, Belal A (2014). Delineation of site-specific management zones by fuzzy clustering of soil and topographic attributes: A case study of East Nile Delta, Egypt. In *IOP Conference Series: Earth Environ. Sci.*, **18** (1), p. 012046). IOP Publishing.

Salem, Z. E., Sefelnasr, A. M. and Hasan, S. S. (2019). Assessment of groundwater vulnerability for pollution using DRASTIC Index, young alluvial plain, Western Nile Delta, Egypt. *Arabian Journal of Geosciences*, **12**(23), 1-13.

Sharaky AM, El Hasanein AS, Atta SA, Khallaf KM (2016). Nile and groundwater interaction in the western Nile Delta, Egypt. *The Nile Delta*, 33-62.

Shokr M, Jalhoum MES, Belal A, Abdou M, Abdelhameed HH (2022). Assessment of Agricultural Sustainability of Bahariya Oasis using Geo-informatics techniques. *Egyptian Journal of Soil Science*, **62**(2), 85-100.

Shyju K, Kumaraswamy K (2019). Exploration of Land Resources for Analyzing the Suitability of Selected Crops in AN Administrative Unit of Thrissur District, Kerala. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, **42,** 435-437.

Sparks DL, Page AL, Helmke PA, Loeppert RH (Eds.) (2020). *Methods of soil analysis, part 3: Chemical methods* (Vol. 14). John Wiley & Sons.

Sys C, Van Ranst E, Debaveye J (1991). Land Evaluation, part 11: Methods in Land Evaluation. ITC, University of Ghent, Belgium, 247 p.

Sys C, Van Ranst E, Debaveye J, Beernaert F (1993). *Land Evaluation. Part III: crop requirements. Agricultural Publications n° 7, GADC, Brussels, Belgium,* 191 p.

Taalab A S, Ageeb GW, Siam HS, Mahmoud SA (2019). Some Characteristics of Calcareous soils. A review AS Taalab1, GW Ageeb2, Hanan S. Siam1 and Safaa A. Mahmoud1. *Middle East J*, **8**(1), 96-105.

Tewksbury BJ, Dokmak AA, Tarabees EA, Mansour AS (2012). Google Earth and geologic research in remote regions of the developing world: An example from the Western Desert of Egypt. *Google Earth and Virtual Visualizations in Geoscience Education and Research: Geological Society of America Special Paper*, **492**, 23-36.

Wahba M, Fawkia LABİB, Zaghloul A (2019). Management of calcareous soils in arid region. *International Journal of Environmental Pollution and Environmental Modelling*, **2**(5), 248-258.

Wood J (1996). The geomorphological characterisation of digital elevation models. University of Leicester (United Kingdom