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Using GIS Tools and Remote Sensing Data to Assessment of Land Capability and Suitability for Agriculture in New Aswan Area, Aswan Governorate, Egypt

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THE WESTERN part of Aswan City in Upper Egypt represents one of the high-priority regions for future development that witness any investment opportunities and agricultural and socioeconomic growth. In this study, we have used soil data and remote sensing in combination with geographic information system (GIS) tools to evaluate land capability and suitability for agriculture. For this purpose, 40 soil profiles were selected to represent the area under study. The land capability of the study area was done using the ASLE program, and the Modified Storie Index. Land suitability of the study area was performed using the ASLE software. The results of the ASLE land capability assessment indicated that about 17.5% (175 hectares) of the total area is good (C2), 17.5% (175 hectares) is fair (C3), and 65% (650 hectares) is poor (C4) soils for agricultural use. Depending on the Modified Storie Index program, the results showed that 75 hectares (7.5%) of the total study area are considered good, 650 hectares (65%) are considered fair, 225 hectares (22.5%) were poor for agricultural use, and 50 hectares (5%) were considered as non-agricultural that have moderate to severe limitations and they are unsuitable for growing crops. The results also revealed that due to the existence of various soil-specific characteristics, the suitability of these soils for the majority of the proposed crops ranged from appropriate (S1) to unsuitable (NS1 and NS2) for the chosen crops. The major limiting factors in the study area for irrigated agriculture were coarse texture, gravel content, sometimes high salinity, alkalinity, and high $CaCO_3$ content.

Keywords: ASLE arid, Land suitability, Land capability, GIS, New Aswan.

1. Introduction

One of the most important objectives of Egyptian agricultural policy is the horizontal agricultural expansion in the western desert to meet the expanding population's needs for food security (Ismail et al., 2010). Aldabaa et al. (2010) reported that Agricultural expansion in new desert areas is also prioritized to offset Egypt's slow loss of agricultural land. The majority of the Aswan Governorate's agricultural land is concentrated in a fairly small strip (up to 5 Km in width) of alluvial soils that runs along the Nile River on both sides. Desert land reclamation is the primary approach to alleviating the social and economic problems that threaten our society (Abd El-Aziz, 2004). Southern Egypt's New Aswan is regarded as one of the most promising regions for the growth and development of agriculture. Land evaluation is a crucial stage in land use planning when resources are available; (land, water, and money) are limited, especially in Egypt. To adequately manage these resources, an assessment of land suitability is always conducted to assess approximately which part of the land is suitable or suitable for a particular location (Bodaghabadi et al., 2015) this study is an important step to assess the potential of the new Aswan region for agricultural sustainable development projects. Lands are evaluated according to their chemical and physical capabilities as well as constraints to protect soil resources from degradation through the potential to fulfill farmers' demands for optimum crop production (Sharififar, 2012). Geographic information systems technique combined with geostatistical analysis is an effective method for assessing the capacity and suitability of land (Sayed and Khalafalla 2021). Images from remote sensing (RS) are an effective technique for studying the

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surface of the Earth and analyzing crop systems (Aldabaa and Yousif, 2020; Jalhoum et al., 2022). Geographic information systems (GIS) and remote sensing (RS) were widely employed in Egyptian studies to map and manage land resources. Furthermore, remote sensing (RS) and geographical information systems (GIS) have been utilized to carry out map analysis approaches for land evaluation (Saleh et al., 2013; Mohamed et al., 2014; Saleh and Belal 2014; Abd El-Azem, 2016; Abd El-Aziz, 2018; Abd El-Azem, 2020 and Ahmed, 2021An important tool for evaluating crop production suitability is the Geographic Information System (GIS). The parameters for land suitability were assessed using these techniques (El Baroudy, 2016). In Egypt, many studies have used GIS and remote sensing for mapping land resources and management (Mohamed et al., 2014; Saleh and Belal, 2014). RS data and soil survey information can be integrated into aGIS to evaluate the crop fit for various soils (Abdel-Rahman et al., 2016). GIS tools enable the integration of several parameters, including elevation, slope, land use, distance to water source, soil texture, soil depth, soil type, and soil drainage to assess land suitability for agriculture (Hagos et al., 2022). The current work aims to apply geographic information systems and remote sensing techniques to identify land resources in the new Aswan area and assess their capability and suitability for agriculture.

2. Materials and methods

2.1. Description of study location and climatic conditions

The area under study is a part of the western desert and is located in New Aswan City, about 20 Km west of the Aswan governorate. Moreover, New Aswan City is located on the west bank of the Nile River, 12 km from Aswan City. The study area is located between latitudes 24° 16' 18" and 24° 18' 44" N and longitudes 32° 46' 32" and 32° 45' 38" E. (Figure 1). The total area covers about 2380 feddans (1000 hectares).

Meteorological data obtained from the Aswan station during the past ten years (2011-2021) showed that the mean annual rainfall of 0.005 mm/ year is concentrated in the autumn and winter seasons where drought prevailed most of the year and there were no wet periods. The average maximum temperature reached 33.05 °C in summer and the mean minimum temperature of 19.93 °C in winter. In addition, the recorded mean relative humidity (RH) was 29.83% and 36.33% is the average yearly relative humidity, and the average annual wind speed is 8.18 km h^{-1} (Table 1). Consequently, it may be concluded that the climate of this area is extremely arid and the natural vegetation in the studied area is very poor. On the other hand, the soil temperature system in the area under study is The US Soil Classification System classifies the soil moisture system as "Torric" and the soil temperature as "Thermic." **(USDA, 2010).**

2.2. Remote sensing and GIS works

In this study, the remote sensing instrument was used and expressed by an Enhanced Thematic Mapper (ETM+) Landsat 8 satellite image dated 2020, at row 42 and track 177 (Figure 2). The bands were selected with a stronger focus on the data's final applications. An assortment of the best possible band combinations (7, 5, and 3) according to NASA (2013**)** was carried out. TIRS bands were acquired with an accuracy of 100 m but were re-sampled to 30 m in the delivered data product. Digital image processing techniques represented by satellite images were performed using ENVI 5.1. ITT (2014) included a subset of images implemented using a spatial subset, while rectification (geometric correction) was performed using the image-to-map method. Digital elevation models (DEM) with a resolution of 10 meters have also been used to monitor soil elevation according to the National Mapping Center (2010). ArcGIS 10.2.2 was used to create geographic information system (GIS) works, such as a base map, geomorphological map, soil attributes, land capability, and land suitability. Map production software (ESRI, 2019) includes pixel, map, and geographic (latitude/longitude) grids, scale bars; north arrows; text and symbols; polygons, polylines, and geometric objects; map keys, legends, and picture insects for presentation or visual analysis and interpretation. Spatial variability maps of soil properties were prepared using geostatistical analysis.

2.3. Field Description and Soil Sampling

A total of forty soil profiles were selected to represent the area under study, according to the geology, topography, and recent aerial photographic maps of the studied area. Soil morphological description was performed according to the soil description standards (FAO, 2006; Schoenberger et al., 2012; Soil Survey Staff, 2014). Global Positioning Systems' "Garmin GPS" was used to record the profiles' locations in the field and plotted on the map (Figure 1). These profiles were excavated to an appropriate depth (150 cm) and described for their morphological characteristics. Based on the vertical morphological differences, soil samples were collected from various layers, air-dried, crushed, sieved through a 2 mm sieve, and then kept in plastic containers for various analyses.

2.4. Analytical Methods

The physical and chemical properties of the studied soil samples were determined at the Faculty of Agriculture laboratories, at Aswan University as follows:

The gravel content was estimated as volume based on Schoenberger et al., (2012). A detailed analysis of the particle size distribution of the soil samples was carried out by the international pipette method as described by Gee and Bander (1986). The soil hydraulic conductivity was measured at saturation under a constant head (Klute and Dirksen, 1986).

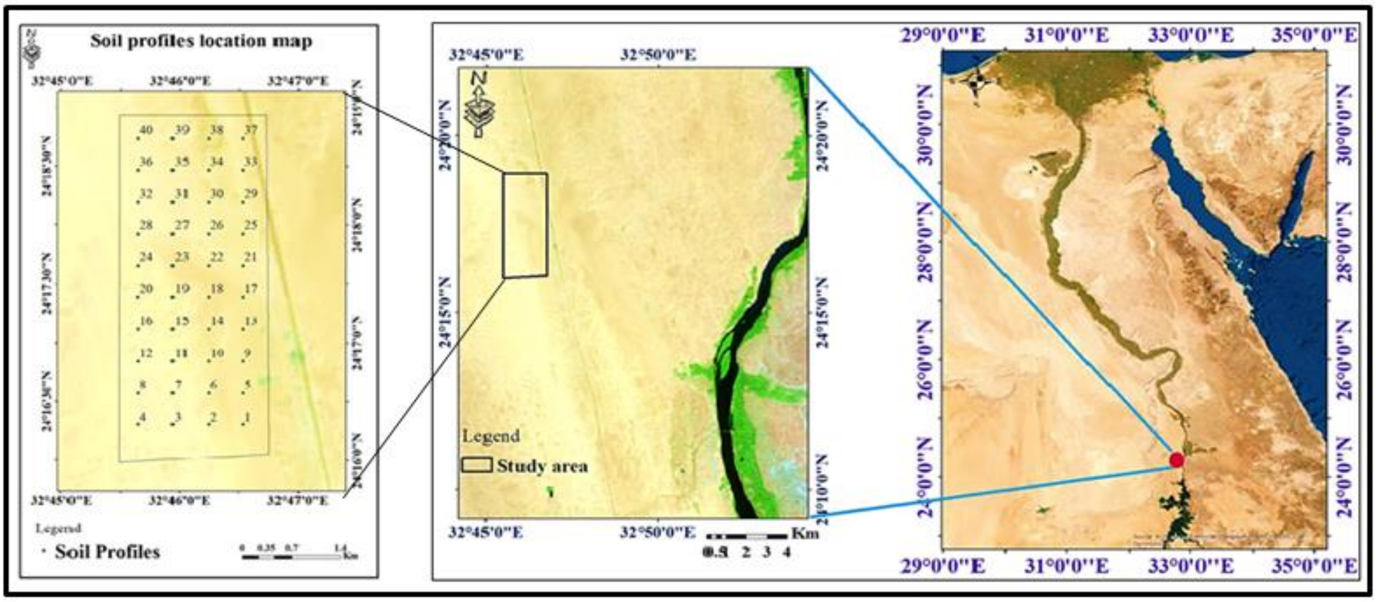

Fig. 1. Location map and soil profiles of the studied area.

Table 1. Average yearly temperature (minimum, maximum, and average), relative humidity (RH), wind speed, and precipitation in the study area from 2011 to 2021 according to the Aswan weather station.

Year	Temperature (°C)			Relative humidity (%)	Wind speed (m/sec.)	Rainfall (mm)
	Min	Max.	Mean			
2011	16.91	35.25	25.33	28.66	3.56	0.00
2012	17.16	31.66	23.83	28.83	2.85	0.01
2013	19.16	32.00	25.33	26.91	3.23	Trace
2014	19.16	32.25	25.16	27.50	2.76	0.02
2015	20.25	30.91	24.25	28.58	3.12	0.00
2016	19.08	32.83	25.50	26.91	3.08	Trace
2017	19.25	33.25	25.91	25.33	3.00	0.01
2018	20.41	33.50	26.08	22.75	3.10	0.00
2019	24.08	34.41	29.58	21.41	3.12	0.01
2020	22.50	33.58	30.50	22.41	4.87	Trace
2021	21.32	33.86	29.82	27.30	4.25	0.00

The soil reaction (pH) was determined in (1:2.5) soil water suspension and the electrical conductivity (EC_e) in saturated soil paste extract was determined according to Page et al. (1982). The organic matter content of the soil samples was determined using the Walkley-Black method (Bashour and Sayegh 2007). Total calcium carbonate ($CaCO_3$) was determined volumetrically using Scheibler's calcimeter according to (Loeppert and Suarez, 1996). Gypsum content was extracted from 1:50 (soil: water) suspension and then precipitated with acetone. The precipitated was dissolved in water and the EC value was measured in the solution. Determination of gypsum was done using the standard of Nelson (1982) and Hesse (1998) showing the relationship between the EC and the equivalent gypsum in solution. The cation exchange capacity (CEC $cmol^{(+)}/kg$) was estimated by using sodium acetate (NaOAC) at pH 8.2 as a saturating solution and 1 M ammonium acetate (NH_4OAC) at pH 7.0 to replace Na with NH_4. The free, sodium was measured with a flame photometer (Jackson 1973; Bashour and Sayegh 2007). The exchangeable sodium (Ex. -Na) was determined by the extraction of 5 g of the soil in 100 ml of 1 M ammonium acetate at pH 7 to replace Na with NH_4 after washing the soil with distilled water to remove the dissolved sodium. The determination of exchangeable sodium was undertaken using ammonium acetate as a saturating solution. The displaced Na^+ ($cmol^{(+)}/kg$) was determined by a flame photometer and the exchangeable sodium percentage (ESP) was calculated according to Jackson (1973) as the following equation:

$$ESP\ (\%) = \frac{Ex.Na\ (cmol^{(+)}/kg)}{CEC\ (cmol^{(+)}/kg)}\ x\ 100$$

The sodium adsorption ratio (SAR_e) of the saturated paste extract was calculated using the following equation described by **Richards (1954)**:

$$SARe = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

2.5. Soil classification

Soil profiles were classified down to subgroups level based on soil classification (Soil Survey Staff, 2022), based on meteorological data, field observations, morphological and analytical soil characteristics.

2.6. Land Evaluation Methods

The land capability and suitability evaluation were done using the following systems.

Land capability classification

For achieving land capability two approaches were utilized, the first method used the Applied System of Land Evaluation (ASLE) program proposed by Ismail and Morsi (2001), and the Modified Storie Index rating proposed by O'Geen et al. (2008) was the second.

Applied System of Land Evaluation (ASLE) uses a quantitative estimation of climate, and soil characteristics, i.e., soil depth, texture, slope, soil pH, salinity, carbonate content, gypsum content, ESP, and CEC were used for evaluation (Figure 2). It was applied to evaluate the land capability of the investigated soils. This software works interactively to compare the characteristics of soil profiles to be evaluated with the generalization levels established for each used capability class (C1, C2, C3, C4, C5, and C6) as presented in Table (2).

Table 2. Land capability classes, soil grades, and rating using ASLE software (Ismail and Morsi, 2001).

Class (C)	Grade	Rating (%)
C1	Excellent	80 – 100
C2	Good	60 – 79
C3	Fair	40 – 59
C4	Poor	20 – 39
C5	Very poor	10 – 19
C6	Non-agricultural	< 10

Modified Storie Index Rating (O'Geen et al., 2008): This system was calculated; by rating and coding for some soil properties using the visual basic application under Microsoft Excel, according to Aldabaa (2012). The calculation was down based on the following equation:

Stori Index Rating = [(A/100) × (B /100) × (C/100) × (X /100)] ×100.

Where:

A= Soil depth (cm)

B= texture

C = slope and

X= other soil factors include; topograhy, drainage, fertility, nutrient level, erosion, microrelief, and alkalinity, as shown in Table (3).

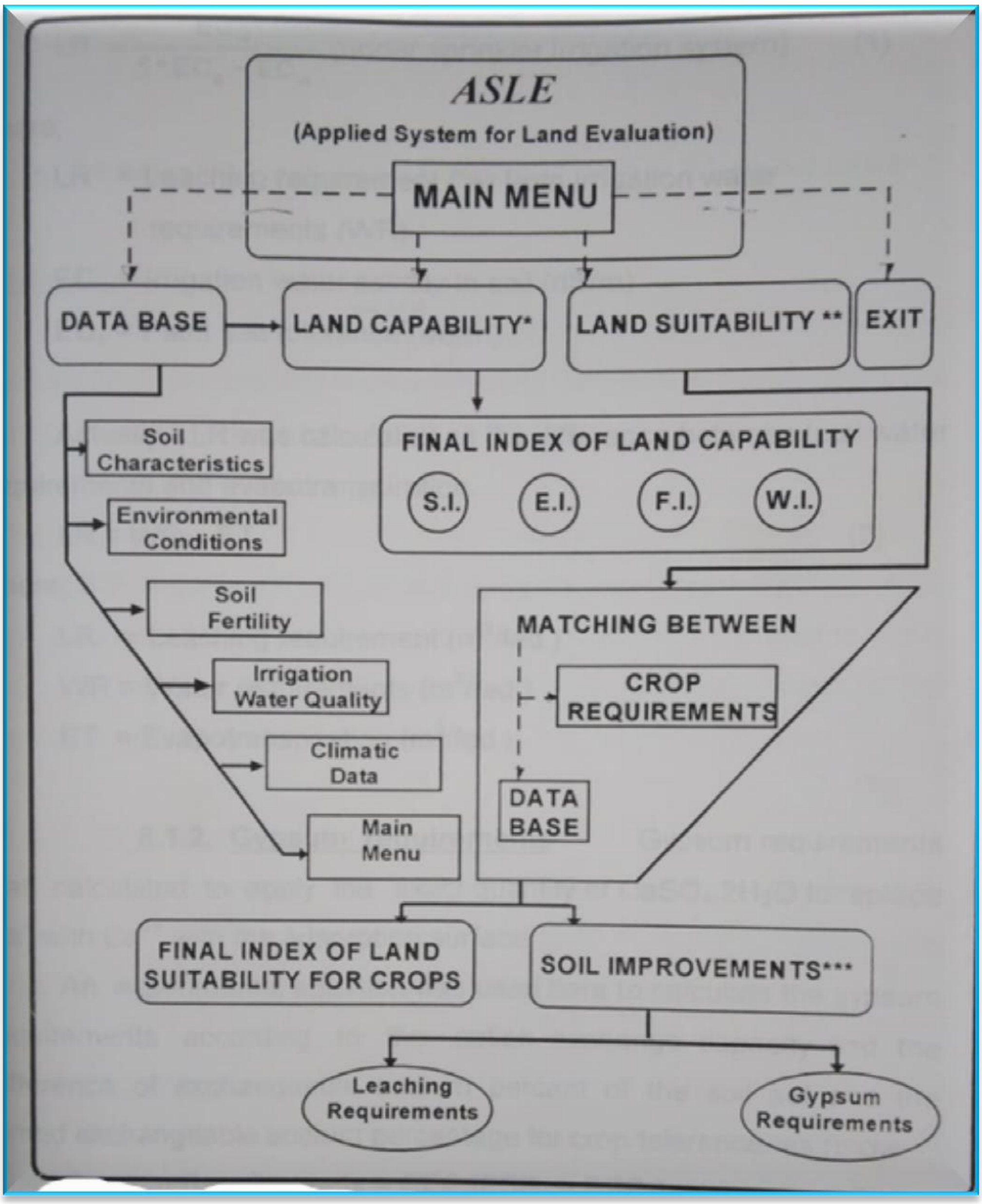

Fig. 2. Flow chart of land evaluation program (ASLE).

Table 3. Land capability classes, soil grades, and productivity rating using the modified storie index (O'Geen et al., 2008).

Soil factor	Soil property	Capability class	Grade	Productivity rating (%)
A	Soil profile depth (cm)	Excellent	1	80 – 100
B	Soil texture	Good	2	60 – 79
C	Slope	Fair	3	40 – 59
X	Other soil factors	Poor	4	20 – 39
		Non-agricultural	5	< 20

2.6.2. Land suitability classification

The land suitability was assessed using the Applied System of Land Evaluation (ASLE) software for arid and semi-arid regions (Ismail and Morsi, 2001). of some Field crops (wheat, barley, maize, soybean, sunflower, and sugarcane), vegetable crops (onion, and tomato), Forage crops (alfalfa and sorghum), and fruit trees (date palm, and citrus) are to be grown on these soils. According to FAO (1976), agricultural requirements and land attributes were matched to generate the software calculations. Table (4) displays land suitability classes, grades, and ratings (description) using ASLE software according to Ismail and Morsi (2001).

Table 4. Soil suitability classes, grade, and productivity index using ASLE software (Ismail and Morsi, 2001).

Class	Grade	Index (%)
S1	Highly suitable	80 – 100
S2	Suitable	60 – 79
S3	Moderately suitable	40 – 59
S4	Marginally suitable	20 – 39
NS1	Currently not suitable	10 –19
NS2	Permanently not suitable	< 10

3. Results

3.1. Soil Physicochemical Properties

Table (5) shows the physical properties of the study soil profiles weighted means. The gravel content (by volume %) of the profile weighted mean ranges from 0.26 to 59.83%. The percentage of sand particles ranged from 55.17 to 99.20%, the percentage of silt ranged from 0.40 to 23.09%, and the percentage of clay ranged from 0.40% to 33.55%. Soil hydraulic conductivity (HC) ranged between 2.64 to 68.25 cmh^{-1}. According to Soil Survey Staff (2022), the soils are classified as Typic Torripsamments, Typic Torriorthents, and Typic Quartzipsamments.

The data in Table (6) showed that the electrical conductivity (EC_e) values ranged between 0.69 and 13.86 dS^{-1}, and the soil pH ranged from 7.84 to 8.83. Organic matter (OM) content was low and did not exceed 1.72 g kg^{-1}. The total carbonate ($CaCO_3$) content ranges between 0.75 and 11.67 %. The percentage of gypsum ranged from 0.31 to 8.71%. The results also showed that the cation exchange capacity (CEC) ranged from 4.86 to 32.19 $cmol^{(+)}$/kg and the exchangeable sodium percentage (ESP) ranged between 1.80 and 16.66%. The profile weighted mean of sodium adsorption ratio (SAR_e) varies between 1.66 and 13.82.

3.2 Land capability and suitability

The results indicated that the land capability grades ranged from 30.52 to 70.54% and 14.94 to 74.68% with the ASLE program and the Modified Storie Index, respectively (Table 7). According to the Applied System of Land Evaluation (ASLE) program, the results indicated that the area is considered highly suitable (S1) for field crops (wheat, barley, maize, soybean, sunflower, and sugarcane) that occupy an area of 10, 12.5, 5, 2.5,10, and 5% of the total studied area, respectively (Table 8). Also, the highly suitable class (S1) is recorded for forage (alfalfa and sorghum) and vegetable crops (onion, and tomato) that covered an area of 12.5, 2.5, 2.5, and 5% of the total area under study, respectively (Table 9). The results also indicate that a highly suitable class (S1) is recorded for date palm that covered an area of 17.5% of the studied area, (Table 8). Moreover, the suitable class (S2) is inscribed for wheat, barley, maize, soybean, sunflower, sugarcane, alfalfa, sorghum, onion, tomato, date palm, and citrus that employs an area of 25, 20, 15, 30, 20, 30, 27.5, 27.5, 25, 30, 45 and 20 % of the total study area, respectively. In addition, the moderately suitable class (S3) is found for wheat, barley, maize, soybean, sunflower, sugarcane, alfalfa, sorghum, onion, tomato, date palm, and citrus which represent an area of 40, 55, 62.5, 37.5, 50, 57.5, 45, 55, 62.5, 47.5, 33, and 60 % of the total studied area, respectively. Meanwhile, the results also indicate that the marginally suitable class (S4) is recorded for wheat, barley, maize, soybean, sunflower, sugarcane, alfalfa, sorghum, onion, tomato, date palm, and citrus which occupies an area of 25, 12.5, 15, 25, 17.5, 7.5, 12.5, 12.5, 7.5, 17.5, 4.5, and 17.5 % of the total studied area, respectively. Moreover, the currently not suitable class (NS1) is found for maize, soybean, sunflower, alfalfa, sorghum, onion, and citrus, which represent an area of 2.5, 5, 2.5, 2.5, 2.5, 2.5, and 2.5% of the total area.

4. Discussions

4.1 Main Morphological Aspects of the Studied Soils

The field description indicated that the topography of the area under study is almost flat, most of the studied soil profiles are located in a semi-flat topography, and the upper surface is almost flat with very few undulating surfaces (Figure 3); the soil surface is covered with the desert pavement of different gravel levels. The elevation varies from 110 to 168 meters above sea level (a.s.l) (Figure 3). All soil profiles of the study area are deep (150 cm) and, which is suitable for agricultural use.

4.2. Soil Physicochemical Properties

The gravel content (by volume, %) was slightly gravelly (<15%) for most soil samples and the profile weighted mean (Figure 3). The results obtained showed that the percentage of sand is dominant in the soil particles in most of the soil samples studied. Figure (4) shows that soils are coarse-textured mainly sand to loamy sand texture. The results achieved correspond to those by Abd Al-Azem (2016), Abd Al-Azem (2020), Saleh et al., (2021) and Fadl et al., (2022). Moreover, the high values of soil hydraulic conductivity (HC) in most of the studied samples may be due to the coarse soil texture, the natural diversity of soil sediments, and hydrological processes, and this reflects the urgent need to drainage practices and manage irrigation (Bhardwaj et al., 2007).

Table 5. Soil profile weighted means of some physical properties of the study area.

Profile No.	Gravel by volume (%)	Particle size distribution (%)			Texture grade	HC (cm h^{-1})	Classification
		Sand	Silt	Clay			
1	59.14	88.48	5.68	5.84	VGS	7.93	Typic Torripsamments
2	0.44	99.20	0.40	0.40	S	34.05	Typic Quartzipsamments
3	4.83	93.55	1.44	5.01	S	24.13	Typic Quartzipsamments
4	4.61	94.64	1.49	3.87	S	9.15	Typic Quartzipsamments
5	27.13	56.83	23.09	20.08	GSCL	2.64	Typic Torriorthents
6	0.73	97.76	0.40	1.84	S	41.67	Typic Quartzipsamments
7	5.30	97.24	0.92	1.84	S	55.97	Typic Quartzipsamments
8	4.14	95.49	1.15	3.36	S	50.94	Typic Quartzipsamments
9	8.79	78.35	7.47	14.19	SL	23.41	Typic Torriorthents
10	13.86	55.17	11.28	33.55	SCL	23.08	Typic Torriorthents
11	8.29	95.60	0.88	3.52	S	22.03	Typic Quartzipsamments
12	8.47	95.09	0.93	3.97	S	52.87	Typic Quartzipsamments
13	7.67	92.45	1.47	6.08	S	34.41	Typic Quartzipsamments
14	2.57	94.27	0.75	4.99	S	23.12	Typic Quartzipsamments
15	3.34	94.44	1.24	4.32	S	21.65	Typic Quartzipsamments
16	0.26	96.48	0.72	2.80	S	49.47	Typic Quartzipsamments
17	1.08	93.04	1.79	5.17	S	33.27	Typic Quartzipsamments
18	1.19	92.73	1.59	5.68	S	29.75	Typic Quartzipsamments
19	6.31	95.88	0.51	3.61	S	58.60	Typic Quartzipsamments
20	11.20	89.84	7.12	3.04	S	21.02	Typic Torripsamments
21	2.99	93.05	2.41	4.53	S	35.43	Typic Quartzipsamments
22	1.73	93.25	1.95	4.80	S	32.35	Typic Quartzipsamments
23	4.89	81.49	15.28	3.23	LS	22.20	Typic Torripsamments
24	2.89	81.41	5.92	12.67	SL	23.5	Typic Torriorthents
25	16.35	95.01	0.83	4.16	GS	77.25	Typic Quartzipsamments
26	22.59	92.88	1.03	6.09	GS	46.28	Typic Quartzipsamments
27	21.93	93.25	1.36	5.39	GS	34.37	Typic Quartzipsamments
28	2.72	86.16	5.07	8.77	LS	16.15	Typic Torripsamments
29	31.88	90.61	3.44	5.95	GS	70.14	Typic Quartzipsamments
30	51.58	95.60	0.77	3.63	VGS	41.41	Typic Quartzipsamments
31	22.46	87.60	4.32	8.08	GLS	13.34	Typic Torripsamments
32	11.35	91.12	2.64	6.24	S	31.34	Typic Quartzipsamments
33	55.14	79.20	12.00	8.80	VGLS	7.18	Typic Torriorthents
34	48.15	86.00	6.96	7.04	VG LS	11.50	Typic Torripsamments
35	41.68	88.53	4.61	6.85	VG S	31.72	Typic Torripsamments
36	35.84	95.55	1.15	3.31	VG S	31.39	Typic Quartzipsamments
37	43.83	86.19	5.36	8.45	VGLS	22.57	Typic Torripsamments
38	59.83	80.67	6.93	12.40	VGSL	26.02	Typic Torriorthents
39	37.89	88.08	4.24	7.68	VGLS	39.40	Typic Torripsamments
40	52.60	78.91	13.63	7.47	VGLS	7.30	Typic Torripsamments
Min.	0.26	55.17	0.40	0.40	--	2.64	--
Max.	59.83	99.20	23.09	33.55	--	77.25	--
Average	18.69	89.03	4.26	6.72	--	31.00	--
STDEV	19.42	9.51	4.90	5.70	--	17.13	--

HC=Hydraulic conductivity S= sand LS= loamy sand GS= gravely sand VGS= very gravely sand VGLS= very gravely loamy sand STDEV = Standard Deviation

Table 6. Some soil chemical properties for weighted profiles mean of the studied area.

Profile No.	EC_e dS/m	pH (1:2.5)	O.M (g/kg)	$CaCO_3$ (%)	Gypsum (%)	CEC (cmole$^{(+)}$/kg)	SAR_e	ESP (%)
1	12.03	8.32	0.2	4.1	0.66	10.61	4.33	7.06
2	0.71	8.07	0.49	1.5	0.31	7.17	2.47	6.14
3	0.85	8.45	0.32	1.74	0.76	9.84	2.11	6.2
4	1.19	8.04	0.32	4.16	1.71	11.66	1.66	6.49
5	12.91	8.01	0.3	0.75	3.19	24.22	13.82	16.21
6	1.66	8.18	0.3	4.91	0.76	4.86	2.77	5.85
7	2.1	8.55	0.28	2.49	1.1	5.69	6.04	7.48
8	3.67	8.44	0.12	2.76	0.76	7.6	2.98	6.71
9	5.15	7.84	0.22	2.22	2.27	13.67	3.93	8.32
10	6.25	8.1	0.15	6.42	6.46	32.19	5.09	6.98
11	2.47	8.6	0.39	2.73	1.38	5.7	6.59	7.3
12	1.32	8.5	0.65	2.08	0.81	5.84	2.01	4.68
13	4.14	8.34	0.22	3	1.29	5.79	4.62	6.22
14	1.27	8.63	0.43	2.85	1.51	7.01	4.1	6.88
15	1.17	8.31	0.07	3.61	1.07	6.88	2.65	6.04
16	1.11	8.37	0.15	3.74	0.71	5.35	2.87	1.8
17	3.55	8.29	0.22	1.42	1.41	7.44	4.09	6.89
18	0.92	8.17	0.25	2.03	1.24	5.95	2.9	4.5
19	1.26	8.6	0.75	1.44	0.98	7.55	2.74	6.56
20	9.2	8.39	0.38	11.67	8.71	9.31	2.17	6.43
21	0.86	8.38	0.61	4.11	1.58	9.06	3.46	5.31
22	0.76	8.17	0.43	2.91	0.97	8.9	2.83	5.13
23	4.08	8.2	0.4	3.94	3.94	17.22	3.97	6.52
24	1.63	8.2	0.52	3.3	4.83	17.11	4	8.47
25	2.66	7.9	0.64	1.93	2.77	8.38	4.54	5.33
26	1.09	8.36	0.13	1.63	1.01	7.34	4.17	6.18
27	0.79	8.31	0.56	2.03	0.94	5.78	1.74	4.32
28	1.2	8.13	1.72	4.81	3.43	12.64	2.81	5.65
29	13.86	8.05	1.43	2.27	2.39	9.7	7.49	9.23
30	3.7	8.4	0.68	1.46	0.98	7.08	4.09	5.37
31	5.52	8.37	0.36	7.03	1.39	16.47	2.7	5.65
32	2.23	8.46	1.29	5.83	1.08	9.87	3.37	10.62
33	10.66	8.02	0.94	1.02	6.08	17.85	5.51	16.66
34	0.98	8.55	0.43	3.54	2.9	17.9	5.13	7.43
35	0.83	8.27	0.41	1.94	1.64	19.73	4.16	5.15
36	1.11	8.39	0.12	6.2	0.76	8.91	2.44	4.87
37	4.91	8.83	0.21	2.85	2.41	17	4.51	4.88
38	11.51	8.4	0.39	0.83	2.48	18.88	3.2	8.68
39	0.69	8.63	0.11	3.29	2.11	13.17	2.86	4.59
40	1.29	8.5	0.41	3.83	2.52	16.66	3.24	5.21
Min.	0.69	7.84	0.07	0.75	0.31	4.86	1.66	1.80
Max.	13.86	8.83	1.72	11.67	8.71	32.19	13.82	16.66
Average	3.58	8.32	0.45	3.26	2.08	11.35	3.90	6.75
STDEV	3.80	0.22	0.36	2.06	1.78	6.02	2.07	2.73

O.M=organic matter CEC= cation exchange capacity ESP= exchangeable sodium percentage
SAR_e= sodium adsorption ratio STDEV = Standard Deviation

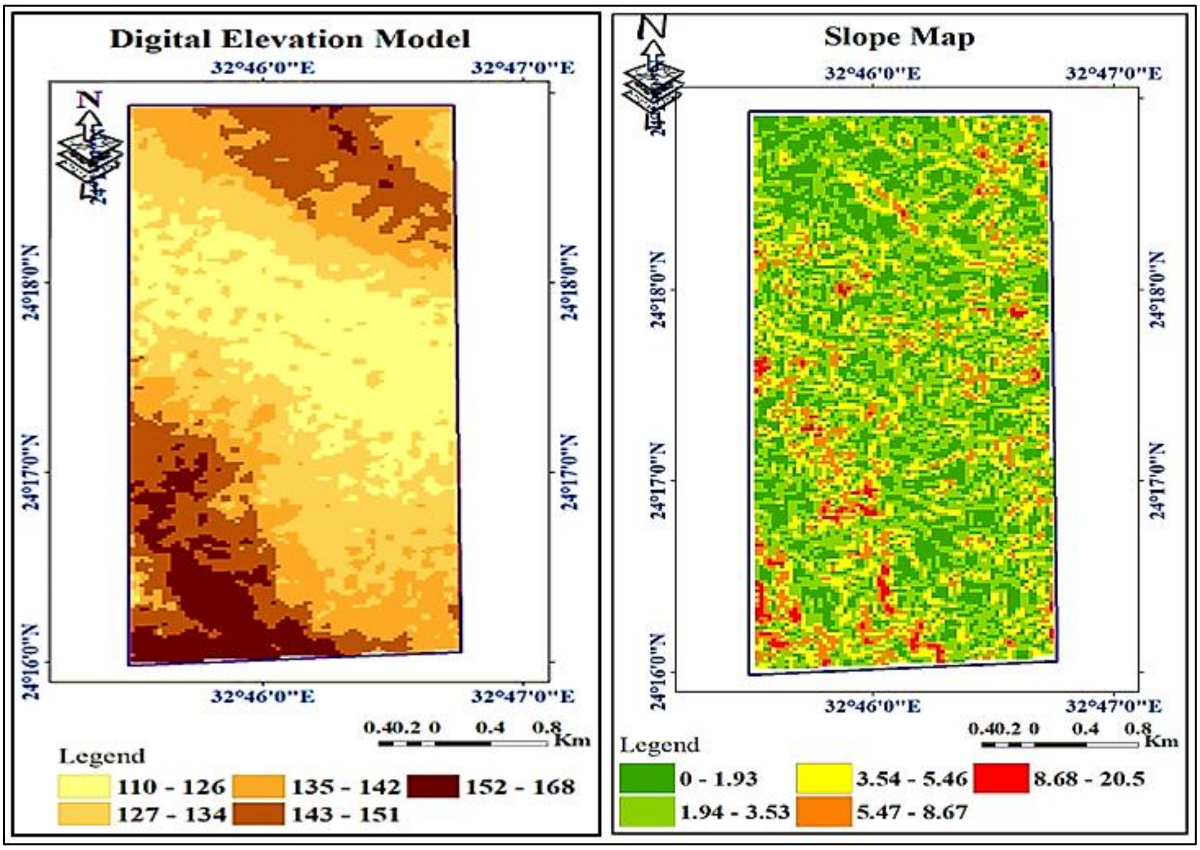

Fig. 3. Digital elevation model (DEM) and slope of the study area.

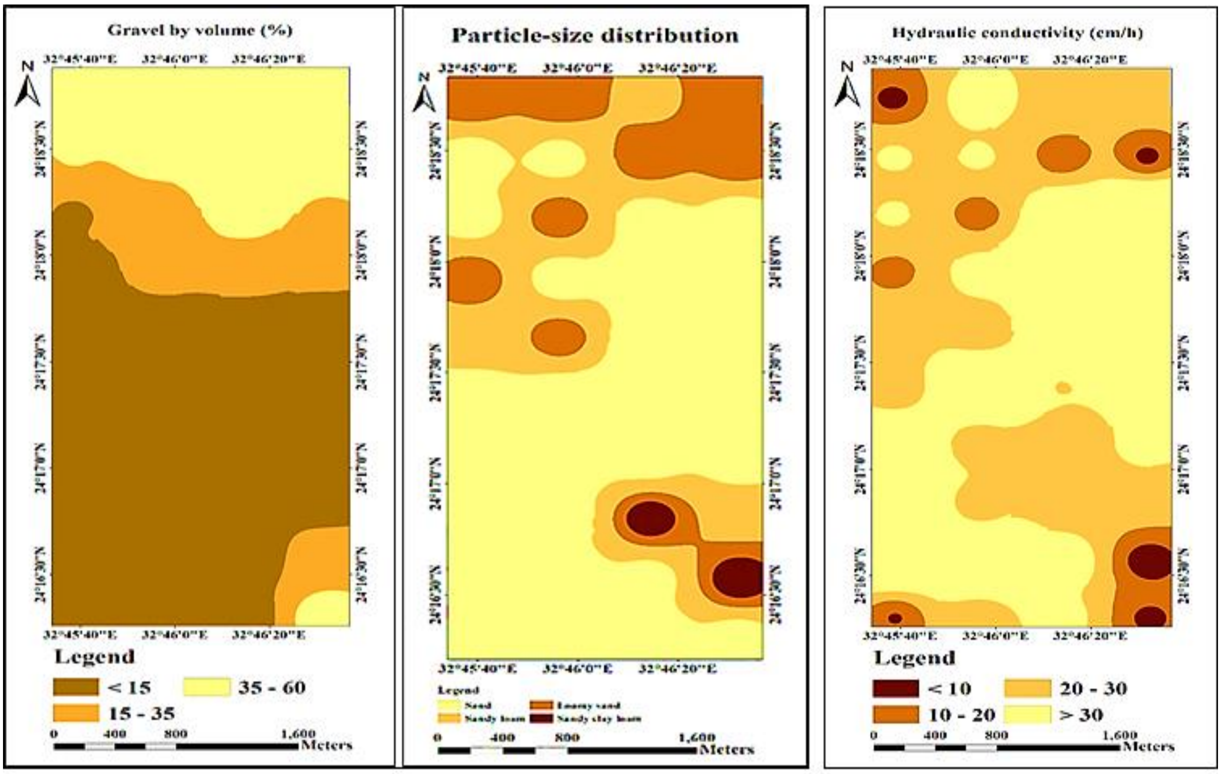

Fig. 4. Soil profile weighted mean values of the gravel content (%), soil texture, and hydraulic conductivity (cm h^{-1}) in the study area.

Figure (5) illustrates that soil pH, is considered moderately to strongly alkaline. The high pH value in some cases may be due to prevailing the base and earth base cations (high base saturation) as well as the total calcium carbonates. Based on the soil reaction (pH) classification by Schoenberger et al., (2012), about 12.4% are slightly alkaline (7.4 to 7.8 pH), 60.0% are moderately alkaline (7.9 to 8.4 pH), 26.7% are strongly alkaline (8.5 to 9.0 pH) and 0.90% of the total soil samples are considered very strongly alkaline which the soil pH value is > 9. According to the salinity classification by Schoenberger et al., (2012), about 7.6 % of the total soil samples of the studied area are non-saline (EC_e < 2 dSm^{-1}), 70.5% are very slightly saline (EC_e 2 to < 4 dSm^{-1}), 11.4 % are slightly saline (EC_e 4 to < 8 dSm^{-1}), 8.6 % are moderately saline (EC_e 8 to < 16 dSm^{-1}), and 1.9 % are strongly saline ($EC_e \geq 16$ dSm^{-1}) (Figure 5). Generally, in most cases, electrical conductivity values increased with depth. Figure (5) showed the organic matter (OM) content was low because of the absence of natural vegetation and the aridity conditions. The examined soil samples illistreated in Figure (6) showed a lack of cation exchange capacity (CEC) due to their coarse texture and shallow organic matter content due to the prevailing dry climate and the arid nature of the soil (Abd Al-Azem, 2020). The results showed that most soil samples in the study area contain ESP values less than 15% (non-sodic), and ESP values increase with depth for most soil profiles. In addition, the highest ESP values are associated with high salinity (ECe) and the predominance of soluble sodium in the soil paste extract the results obtained matches those of Abd Al-Azem (2016) and Abd Al-Azem (2020). The profile weighted mean of the sodium adsorption ratio (SARe) is low in most soil samples and similar to ESP. Figure (7) demonstrates that most soil profiles are slightly calcareous and the surface layers of soil samples have relatively higher calcium carbonate than the subsurface ones. This is possibly attributed to the calcareous sediments being of aeolian origin in the surface layers. The results achieved correspond to those of Aldabaa et al., (2010), Sayed et al., (2016), and El-Desoky and Sayed (2019). Also, gypsum content (Figure 7) is low in most soil layers. According to the classification of gypsum content by FAO (2006), about 94.3 % of the total soil samples are slightly gypsiric (0-5%), while 5.7 % are considered moderately gypsiric (5-15%).

4.3. Soil classification

According to Soil Survey Staff (2022), the soils of the study area are classified as Typic Torripsamments, Typic Torriorthents, and Typic Quartzipsamments (Table 2 and Figure 7).

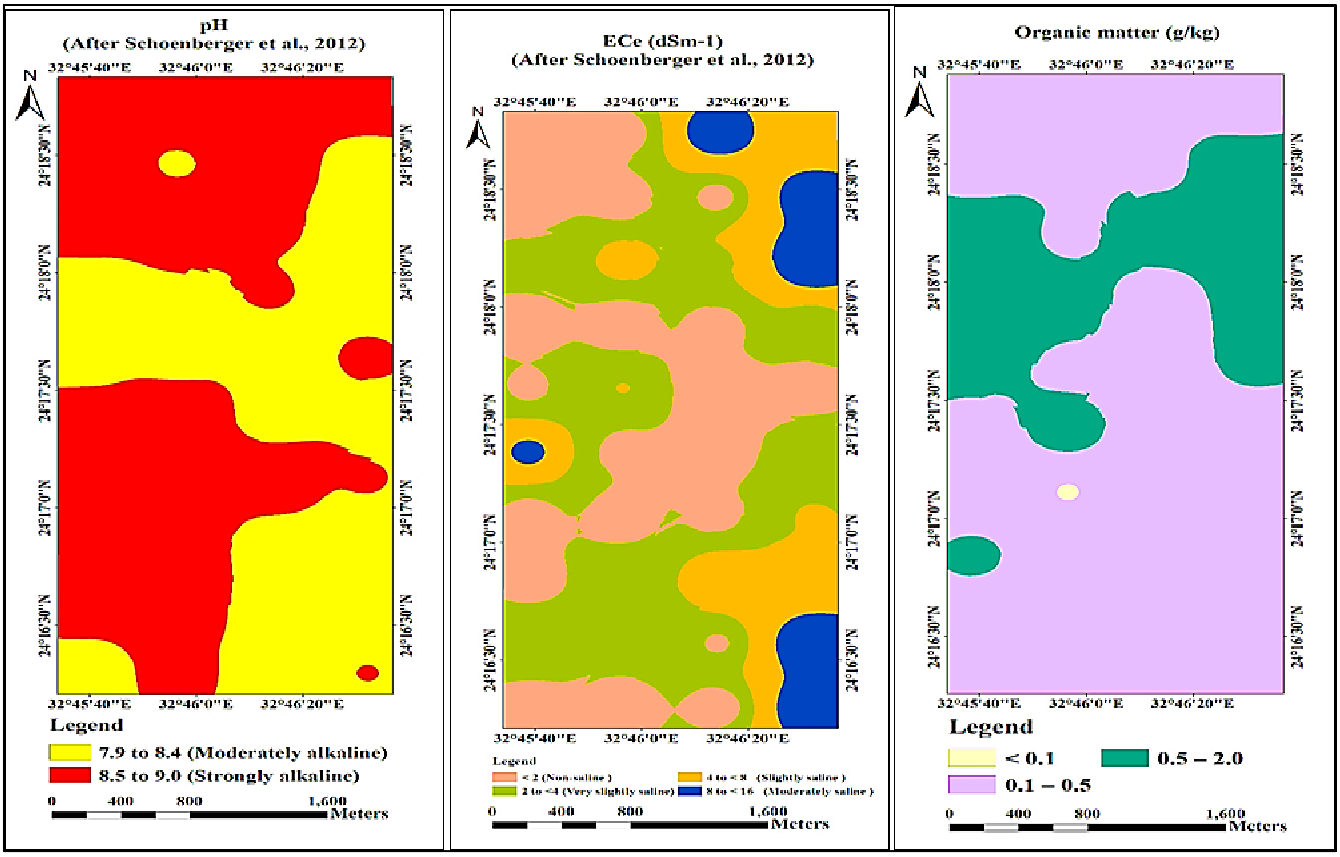

Fig. 5. Soil profile weighted mean values of soil pH, soil salinity (EC_e), and organic matter (g/kg), of the study area.

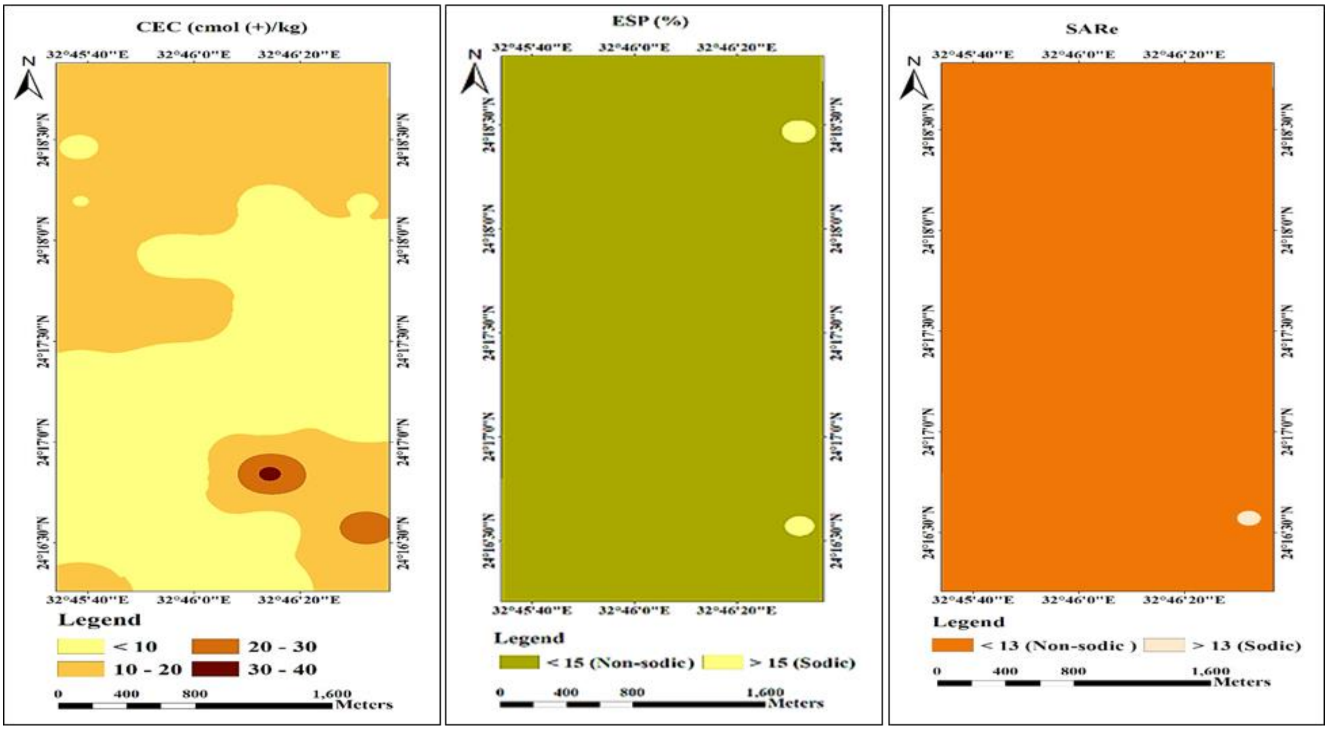

Fig. 6. Soil profile weighted mean values of CEC (cmol$^{(+)}$/kg), ESP (%) and SAR of the study area.

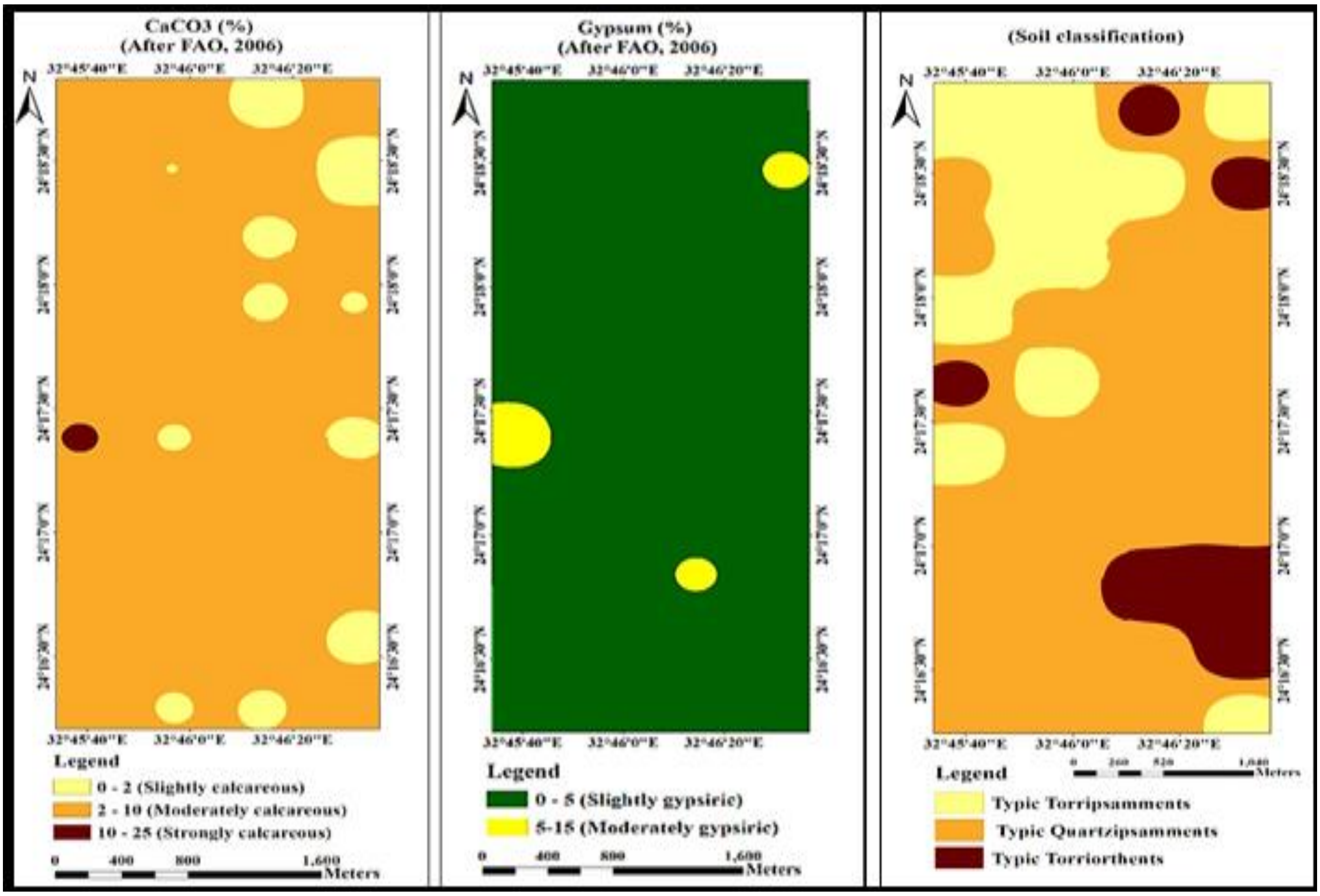

Fig. 7. Soil profile weighted mean values of $CaCO_3$ (%), gypsum content (%), and the soil classification map of the study area down to the subgroup level of the study area.

4.4 Land capability assessment using ASLE program and Modified Storie Index:

According to the ASLE program, the soils of the study area were classified into three capacity classes, which are good (C2), fair (C3), and poor (C4) as shown in Figure (8). On the other hand, soils were classified into four grades, based on the Modified Storie Index (Figure 8), which are good (grade 2), fair (grade 3), poor (grade 4), and very poor (grade 5). Generally, the major limiting factors in the study area are slope, erosion risks, gravel content, soil texture, and low fertility. Decision-makers as part of future use planning should consider this.

Soils with Good (C2) land capability: Soils in this class cover an area of 175 hectares (416.67 feddans) and represent about 17.5% of the total studied area with a capability index (Ci) that ranges from 60.85 and 70.54 % (ASLE program). While this class with Modified Storie Index covered 75 hectares (178.57 feddans) and represented about 7.5% with a capability index (Ci) that varies between 60.54 to 74.68% (Table 7). These soils have minor limitations; the main limitations of these soils are coarse texture and erosion risks. These lands require continued good management practices. In this case, soil productivity will be moderately high to high for a good variety of crops.

Soils with fair (C3) land capability*:* This class included most of the soil profiles studied, with a capability index (Ci) that varies between 44.32 and 85.42 % (ASLE program) and 40.05 to 55.33% (Modified Storie Index). This class covered about 650 hectares (1547.61feddans) and occupies about 65% of the total study area using both the ASLE program and the Modified Storie Index (Table 7). Soils in this class have limitations that require moderately intensive management practices moderately restrict the range of crops, or both. The main limitations of these soils are coarse texture, low CEC, and salinity.

Poor (C4) land capability soils*:* these soils have limitations that need specific conservation and management techniques, which significantly limit the range of crops that may be grown there. There are certain restrictions with this soil such as coarse texture, salinity, low CEC, and gravel. It has a low soil capability index (30.52 to 37.84%) and (14.94 to 37.76 %) with the ASLE program and Modified Storie Index, respectively. This class covered about 175 hectares (416.67 feddans) and represented about 17.5% of the total studied area using the ASLE program, while with Modified Storie Index it covered about 225 hectares (535.71feddans) and occupied 22.5% of the investigation studied area (Table 7). These soils require good and proper management. However, the limitations in this class are non-permanent. Therefore, with good management techniques, the category of these soils could be improved to be "fair or good".

3.4. Land suitability assessment using ASLE program

The current study evaluates the soil suitability for several crop types using the Applied System of Land Evaluation (ASLE) tool. According to Table 8, the soils under study exhibit a broad range of suitability for cultivating crops: highly suitable (S1), suitable (S2), moderately suitable (S3), marginally suitable (S4), and non-suitable (currently not suitable, NS1), and permanently not suitable, NS2). The soil properties that were used for estimating the suitability index for various crops were climate, slope, soil texture, drainage, soil profile depth, calcium carbonate content, soil pH, gypsum status, soil salinity, and sodicity. The studied soil profiles were evaluated to determine their suitability for seventeen crops, drawn by GIS (Arc GIS, 10.2.2). The ASLE program was used to assess the suitability of the soils for twelve crops, which were categorized into four groups as follows: Field crops (wheat, barley, maize, soybean, sunflower, and sugarcane).Vegetable crops (onion, and tomato) Forage crops (alfalfa and sorghum). Fruit trees (date palm, and citrus). According to this program, most of the area under study was considered suitable for growing crops. Moreover, the result revealed that the suitability of those soils for most of the suggested crops ranged from highly suitable (S1) to not suitable (NS1) classes for the selected crops due to the presence of some soil limiting factors (Figure 9 and 10).

Table 7. Land capability index, grade, soil limitation, Representative profile, and total area according to ASLE program, and the modified Storie Index.

ASLE Program							Modified Storie Index						
Capability index	Grade	Soil limitation	Representative profile (No).	Area			Capability index	Grade	Soil limitation	Representative profile (No).	Area		
(Ci %)				Hectare	Feddan	(%)	(Ci %)				Hectare	Feddan	(%)
60 -79	Good	Texture	5, 9, 10, 11, 19, 24, and 28.	175	416.67	17.5	60-79	Good	Texture	9, 24, and 28	75	178.57	7.5
40 – 59	Fair	Texture, CEC and, EC_e	2, 3, 4, 6, 7, 8, 12, 13, 14, 15,16, 17, 18, 20, 21, 22, 23, 25, 26, 31, 34, 35, 36, 37, 39, and 40	650	1547.61	65	40-59	Fair	Texture, CEC and EC_e	2, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 25, 27, 31, 32, 35, 36, and 39	650	1547.62	65
20 – 39	Poor	Texture, gravel, CEC and, EC_e	1, 27, 29, 30, 32, 33, and 38.	175	416.67	17.5	20-39	Poor	Texture, CEC and EC_e	5, 20, 26, 30, 33, 34, 37, 38, and 40	225	535.71	22.5
							< 20	Very poor	Texture, CEC, EC_e, slope, gravel, and SAR_e	1 and 29	50	119.05	5
Total				1000	2380.95	100	Total	---	---	---	1000	2380.95	100

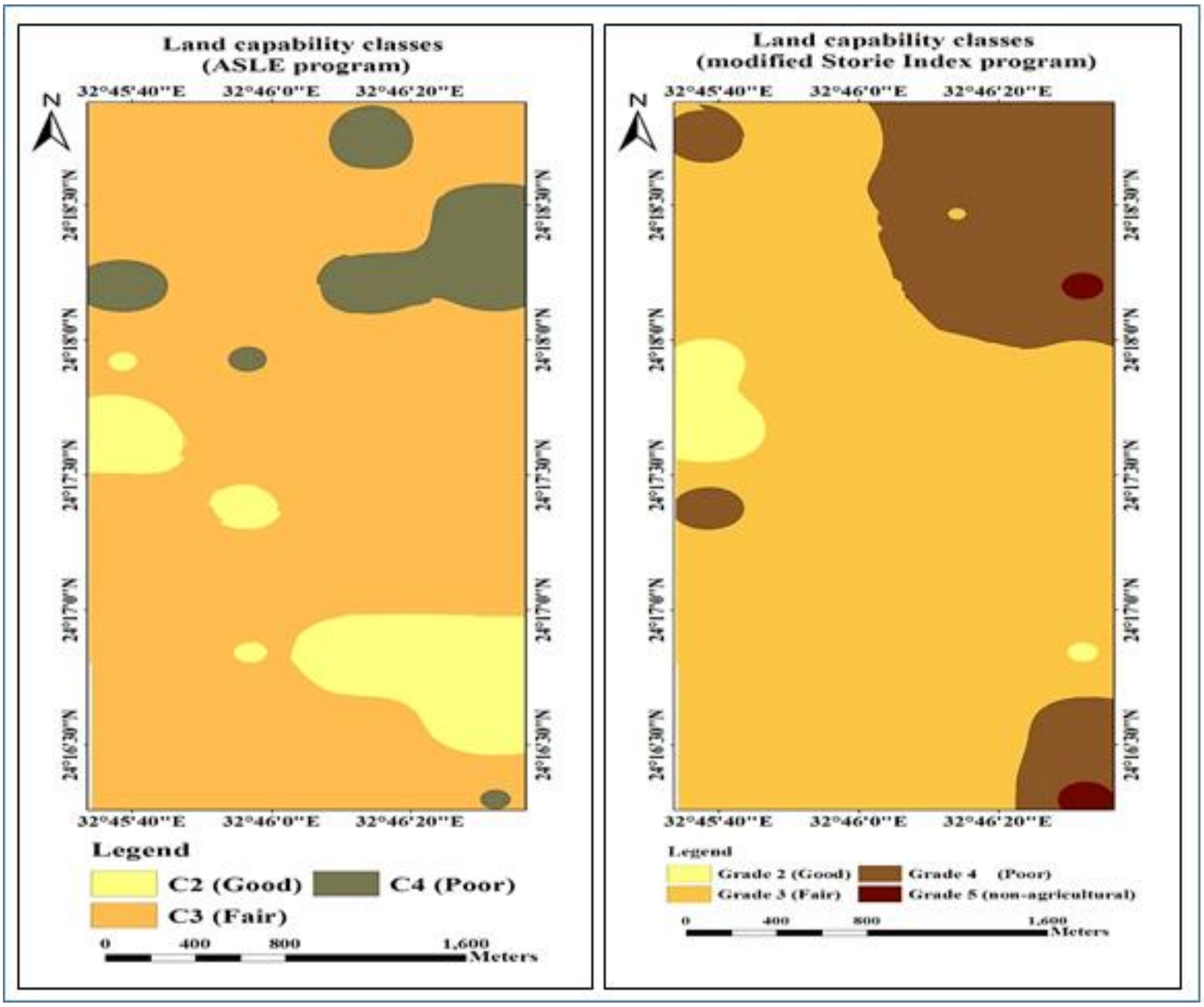

Fig. 8. Land capability classification of the study area using ASLE program and Modified Storie Index program.

Table 8. Soil suitability rating and percentage for growing field, forage, vegetable crops, and fruit trees according to the ASLE program (Ismail and Morsi, 2001).

Suitability Rating	Field crops						Forage crops		Vegetable crops		Fruit trees	
	Wheat	Barley	Maize	Soybean	Sunflower	Sugarcane	Alfalfa	Sorghum	Onion	Tomato	Date palm	Citrus
S1	10	12.5	5	2.5	10	5	12.5	2.5	2.5	5	17.5	--
S2	25	20	15	30	20	30	27.5	27.5	25	30	45	20
S3	40	55	62.5	37.5	50	57.5	45	55	62.5	47.5	33	60
S4	25	12.5	15	25	17.5	7.5	12.5	12.5	7.5	17.5	4.5	17.5
NS1	--	--	2.5	5	2.5	--	2.5	2.5	2.5	--	--	2.5

S1 = highly suitable (80 -100%) S2 =suitable (60 - 80%)
S3 = moderately suitable (40 - 60%) S4 =marginally suitable (20 - 40%)
NS1 =currently not suitable (10 - 20%)

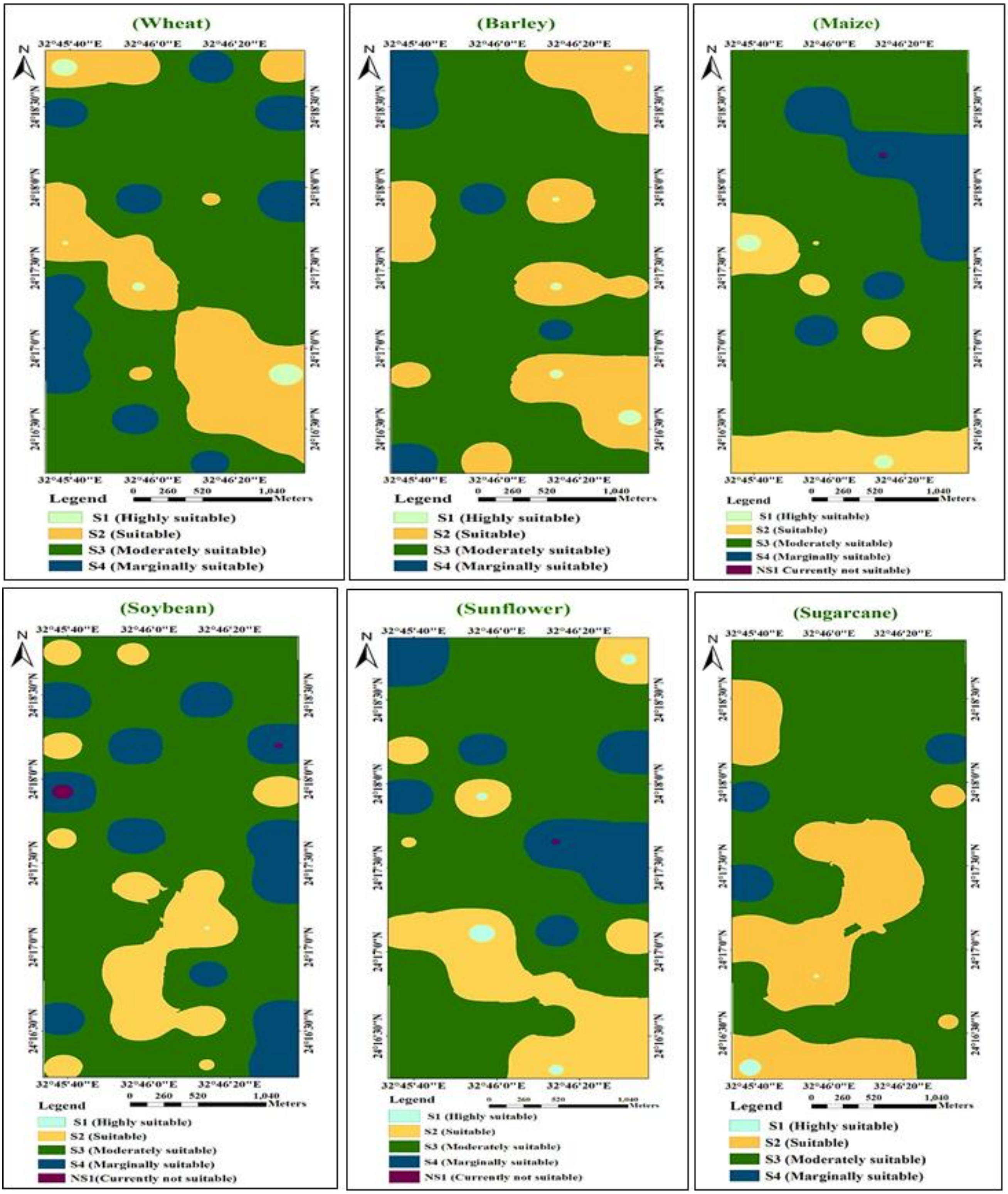

Fig. 9. Land suitability map of wheat, barley, maize, soybean, sunflower, and sugarcane crops in the studied area.

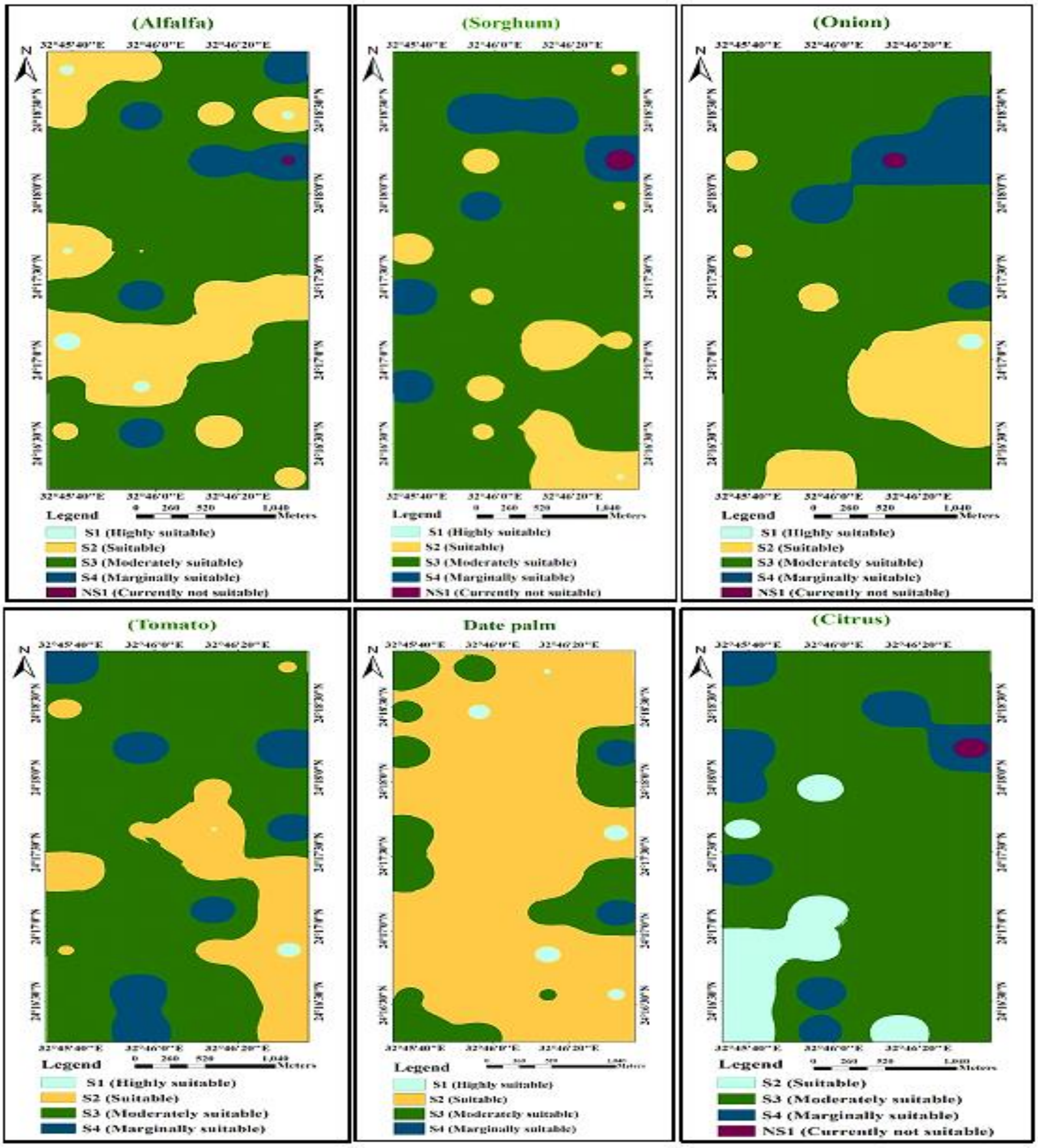

Fig. 10. Land suitability map of onion, tomato, alfalfa, sorghum, date palm, and citrus crops in the studied area.

5. Conclusion

The area under study is located in the new Aswan city, about 20 Km west of Aswan governorate. It is considered a part of the western desert (El-Gallaba plain). The area under investigation is regarded as one of the most suitable areas for agricultural expansion. The majority of the crops that were chosen are favorable for cultivation in this area. Moreover, the data show that the larger area (40-65%) of the soil under study was moderately suitable (S3) for growing most of the selected crops. Additionally, assuming the water requirements of the crops are satisfied, the results indicate that the soil under study has good potential for yielding crops under surface and drip irrigation systems. On the other hand, these crops are most suitable in arid and semi-arid regions. On the other hand, dry and semi-arid locations are the most suitable for these crops. The main limiting factors of the studied soils for irrigated agriculture were coarse texture, gravel content, alkalinity, high salinity, high $CaCO_3$ content, high pH, high ESP, and low fertility, so these limitations can be improved to achieve sustainable agricultural use of these soils by the following:

1. Good soil management, especially agricultural practices, and optimum agricultural cycle.
2. Using high-quality irrigation water and appropriate fertilization and management in conjunction with intense leaching might enhance the soil's adaptability for growing the different crops under consideration.
3. Continuous addition of organic matter to improve the properties of these soils.
4. Use of some soil conditioners and fertilizers that have an acidic effect.
5. Use of sprinkler and drip irrigation systems.

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