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Development of Land Capability and Suitability Maps for Bahariya Oasis, Egypt

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THE SOILS in Bahariya Oasis are promising for land reclamation projects due to their location and availability of groundwater resources for crop irrigation. The objectives of this work were to evaluate land capability of soils in Bahariya Oasis and to make an assessment of their suitability for certain crops. For this purpose, 31 geo-referenced soil profiles were dag, field described and classified. Also, 68 soil samples were collected from these profiles and analyzed for their physical and chemical properties. Water samples were also collected from irrigation wells and analyzed for their chemical quality parameters. Land evaluation was carried out using the Agriculture Land Evaluation System for arid and semi-arid regions (ASLEarid).

The obtained results indicated that soils in Bahariya Oasis were located into three capability classes, which are good (C2), fair (C3) and poor (C4). The first class (C2) was represented by only one soil map unit (SMU10). Soils in that SMU have fair soil index (SI) and low soil fertility index (SFI). The second class (C3) included most of the studied SMUs (2, 3, 4, 5, 6, 8, 9 and 11). Soils in that class have poor to fair SI and SFI. The third class (C4) included SMUs 1 and 7. Soils in that class have poor SI and SFI. Poor land capabilities were found to be associated with poor soil texture, high salinity, low available water, high hydraulic conductivity and low fertility. However, these limitations are not permanent and most of them can be improved through proper management practices.

Land suitability for the selected field crops showed that wheat, sunflower and alfalfa were highly (S1) to conditionally suitable (S4), whereas barely, peanut, maize, faba bean and sugar beet were moderately high (S2) to conditionally suitable (S4) in all SMUs. On the other hand, the selected vegetable crops showed that tomato and watermelon were highly (S1) to conditionally suitable (S4) and onion, pea, pepper and potato were moderately high (S2) to conditionally suitable (S4) in all SMUs. The selected fruit trees ranged from highly suitable (S1) to actually unsuitable (NS2) with date palm and fig, whereas olive, grape, citrus and pear ranged from moderately high (S2) to actually unsuitable (NS2) in most of the soils. Non-suitable areas were due to soil depth restrictions and high salinity, which can be modified through appropriate management practices.

Keywords: Soil evaluation, Land capability, Land suitability, ASLEarid, GIS.

Introduction

Bahariya Oasis is a great depression in the Western Desert of Egypt. Soils in that oasis have a great potential for land reclamation projects due to their location and availability of good quality groundwater for crop irrigation (Elnaggar, 2014). Accordingly, the capability of these soils for agricultural production has to be evaluated and their suitability for certain potential crops has to be tested.

Many systems have been developed for evaluating agricultural limitations that affect land capability under the prevailing conditions. All systems aim to gain better knowledge and understanding of the soil properties and defining limitations affecting their agricultural potentialities. Accordingly, land evaluation is a knowledge-based system; therefore it requires an extensive knowledge and different conditions to be fulfilled. This can be done automatically by using land evaluation systems such as ALES, LECS and GIS (Sys et al., 1991 and Ganzorig, 1995).

The most widely used categorical systems for evaluating agricultural land is termed land capability classification. The capability classification provides three major categories of soil grouping: classes, subclasses and units (FAO, 2007). This system contains seven capability classes. These classes are groups of land units according to their degree of limitations and the risks of soil damage. The limitations increase progressively from class one to class seven.

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Huizing et al. (1995) and Edoardo (2009) have defined land capability as "the ability of land to accept a type and intensive of use permanently, or for specified periods under specific management, without permanent damage". It will be based on assessment of biophysical land recourses information that is currently available.

The second "land suitability" is defined as "the fitness of a given type of land for a specified kind of land use, under its present condition (actual suitability) or after improvement (potential suitability)" (Mousa, 2010). Land suitability also defined as "the fitness of a given type of land for a defined use" (FAO, 2006). The general classification of land suitability was proposed by the FAO. This classification is universally accepted for the purposes of land use planning, primarily in the developing countries. Two suitability orders are distinguished in this system, which are: suitable (S) and unsuitable (N). The first order (S) is subdivided into very suitable (S1), moderately suitable (S2), and marginally suitable (S3). The second order (N) is subdivided into currently unsuitable (N1) and permanently unsuitable (N2). A land suitability map illustrates the suitability of each soil map unit (SMU) for certain type of land use.

The main objectives of this work were to evaluate land capability of soils in Bahariya Oasis and to make an assessment of their suitability for certain crops. Developing land capability and suitability maps of soils in Bahariya Oasis will help in establishing a decision making framework for future planning of the that region.

Material and Methods

Site description

Bahariya Oasis covers an area of about 2100 km^2 and it is located between latitudes 27° 48' - 28° 30' N and longitudes 28° 35' - 29° 10' E as represented in Fig. 1. It represents a great depression in the Western Desert of Egypt and it is surrounded by high scarps. The oasis is characterized by an extremely arid conditions, where air temperature varies from (10-20 ^{o}C) in winter and from (20-30 ^{o}C) in summer. Mean annual precipitation is about 4 mm. Soils in Bahariya Oasis are generally characterized by a hyperthermic soil temperature regime and torric soil moisture regime. Elevation of the oasis varies from 73 to 358 m above sea level (ASL). Most of the oasis surface is almost flat with isolated hills scattered all over the oasis. Geology of Bahariya Oasis consists of these formations ordered from greatest to lowest: Bahariya sandstone and variegated shale (Cretaceous), El-Heiz formation, EI-Hufhuf formation, Ain Giffara formation, Khoman chalk (Cretaceous), plateau limestone (Upper Middle and Lower Eocene), and volcanic rock (Oligocene) (Salem ,1980 & 1987 and Khalifa *et al.,* 2006).

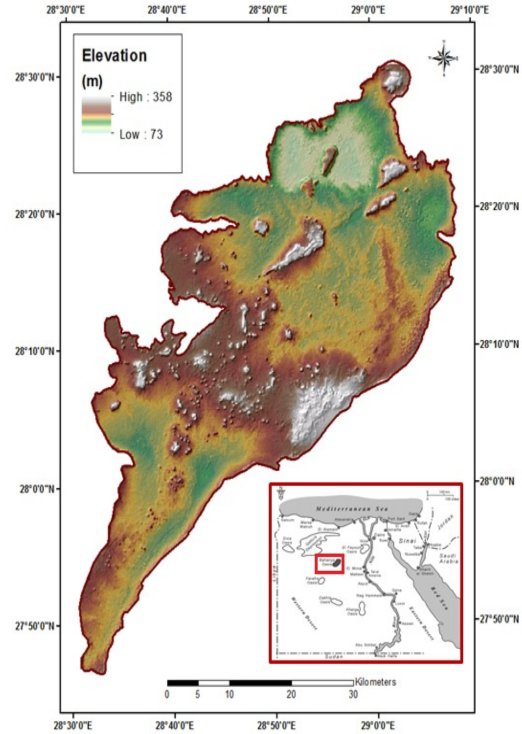

Fig.1. Location map of Bahariya Oasis and its topography

Physiographic units and filed work

Spot 4 images (acquired in 2011) and digital elevation model of the Oasis (developed from the SRTM data) were used to define the physiographic map in the studied area. Three physiographic units were developed, which are: 1) plains, 2) depression floor with low, moderately high and high lands, and 3) pediment as illustrated in Fig. 2. Thirty - one soil profiles were selected to represent the identified physiographic units. The exact locations of these profiles were precisely defined by using the Global Positioning System (GPS). The spatial distribution of these soil profiles is illustrated in Fig. 2. Soil profiles were described in the field according to procedures described by the USDA-NRCS (2002) and they were classified according to U.S. soil taxonomy (Soil Survey Staff, 2010). A total of 68 soil samples, representing the different soil horizons of the selected profiles were collected, air-dried, crushed to pass through 2 mm sieve, and stored for physical and chemical analyses.

Soil and water analyses

Soil physical and chemical analyses were carried out according to the methods described by the Soil Survey Staff (2014). In addition, chemical analyses of water samples were performed using the same methods.

Land capability and suitability evaluation

Land capability and suitability evaluation was carried out using the Agriculture Land Evaluation System for arid and semi-arid regions (ASLEarid) which has been developed by Ismail *et al.* (2005). This model is integrated as an extension with ArcGIS software package to facilitate the calculation of the final soil capability index and suitability classes for certain crops. It takes into account three major factors: soil physical and chemical characteristics, soil fertility status, and irrigation water quality. It helps in calculating land capability indices and in the assessment of soil suitability for various crops. It also displays the output results in simple and handy maps that show the spatial distribution of each index and land suitability for certain crop all over the studied area. Land capability maps for the studied area were developed based on the produced soil map for the oasis.

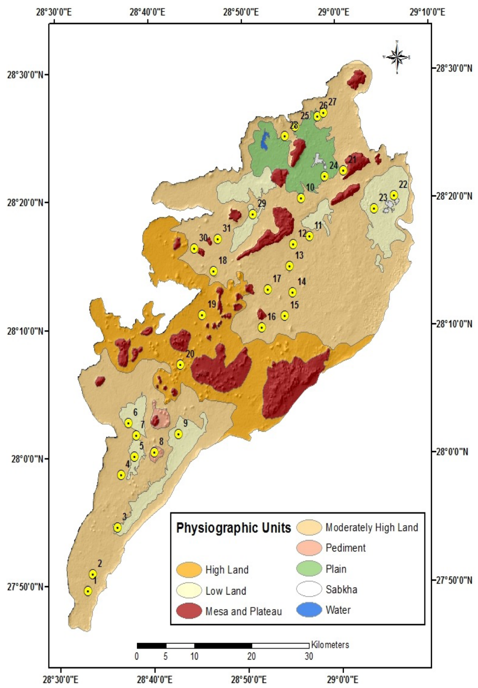

Fig. 2. Physiographic map units and locations of studied soil profiles

Results and Discussions

Soil physical and chemical properties

Tables 1 and 2 show soil physical and chemical soil properties of some representative soil profiles for SMUs in the studied area. Total sand varied from 41.48 to 91.79 %, silt ranged between 4.86 and 30.42%, and clay varied from 3.05 to 28.73%. Soil texture ranged between clay loam and sandy, which is the dominant texture. Total carbonate ranged between 2.06 to 19.53 %, with an average of 6.26%. Soils were poor in their content of organic matter (0.14 to 1.57 %, with an average of 0.74%). Saturation percentage (SP) varied from 22 to 47 %, with an average of 32%.

Sodium was the predominant cation in all horizons followed by calcium and magnesium (111, 42, and 26.65 meq L^{-1} in average, respectively). On the other hand, chloride was the dominant anions followed by sulfates and bicarbonate (106, 68.32, and 5.57 meq L^{-1} in average, respectively). Soil pH ranged between 7.12 and 8.80 (7.92 in average). Soils were very saline, where the electrical conductivity (EC) varied from 2.10 to 46.30 with an average of 17.78 dS m^{-1}. Cation exchange capacity (CEC) varied from 2.71 to 20.05 (10.52 meq/ 100 g soil in average). Exchangeable sodium percentage (ESP) varied from 11.79 to 14.65 (12.96 in average). Gypsum content ranged between 1.05 to 6.14% (3.67% in average). Available nitrogen ranged between 15.30 and 66.80 ppm (38.33ppm in average). Available phosphorous varied from 2.37 to 18.17 ppm (10.42 ppm in average). Available potassium ranged between 78 and 264 ppm (168 ppm in average). The C/N ratio varied from 1.55 to 42.5 with an average of 16.04.

Land capability indices

Soil index

Soil index was evaluated based on eleven soil parameters, which are: clay content, available water (AW), hydraulic conductivity (Ks), soil depth (SD), groundwater depth, pH, total carbonates, gypsum, exchangeable sodium percentage (ESP), cation exchange capacity (CEC), and electrical conductivity (EC). Soils in the studied area set in four classes according to their soil index as represented in Fig. 3. These classes are good (C2), fair (C3), poor (C4), and very poor (C5), which represent about 0.4, 26.6, 57.3, and 5.8 % of the studied area, respectively.

TABLE 1. Soil physical analysis for some representative profiles of soil map units (SMUs) in Bahariya Oasis

SMU	Prof. No	Depth cm	Coarse Sand %	Fine Sand %	Total Sand %	Silt %	Clay %	Texture*	$CaCO_3$ %	O.M %	SP %
SMU1	P11	0-5	3.98	85.88	89.86	5.93	4.21	S	17.86	0.30	23.80
		5-13	3.13	86.44	89.57	6.01	4.42	S	15.91	0.36	23.90
		13-33	2.91	86.25	89.16	6.13	4.71	S	20.75	0.39	24.30
		33-46	2.40	85.42	87.82	7.11	5.07	S	19.53	0.44	24.70
SMU2	P18	0-3	6.09	84.03	90.12	5.83	4.05	S	5.09	0.28	24.30
		3-19	5.56	84.13	89.69	5.92	4.39	S	4.98	0.33	24.50
		19-40	5.12	83.93	89.05	6.18	4.77	S	4.79	0.41	24.80
		> 40	4.33	83.29	87.62	7.22	5.16	S	4.45	0.46	25.70
SMU3	P28	0-3	8.16	58.26	66.42	17.33	16.25	SL	4.20	0.78	34.50
		3-13	7.67	56.11	63.78	19.10	17.12	SL	4.03	0.81	34.80
		13-56	6.12	55.37	61.49	20.12	18.39	SL	3.53	0.90	35.90
SMU4	P22	0-12	3.88	38.89	42.77	29.33	27.90	SCL	2.29	1.46	46.10
		12-60	2.97	38.51	41.48	30.42	28.10	SCL	2.06	1.57	47.00
SMU5	P2	0-3	4.98	38.75	43.73	28.95	27.32	SCL	2.47	1.36	46.50
		3-35	4.77	38.56	43.33	29.07	27.60	SCL	2.35	1.41	46.80
SMU6	P27	0-3	7.66	80.30	87.96	6.73	5.31	S	8.16	0.51	25.80
		3-16	5.87	50.62	56.49	21.98	21.53	SCL	10.49	0.62	27.50
		16-41	2.50	28.12	30.62	33.15	36.23	CL	11.52	1.05	39.30
		> 41	3.52	22.64	26.16	34.12	39.72	CL	13.71	1.27	43.10
SMU7	P17	0-100	1.92	89.87	91.79	5.16	3.05	S	-	0.14	21.90
SMU8	P30	0-18	2.83	88.56	91.39	4.86	3.75	S	5.32	0.23	23.60
		18-45	3.75	87.17	90.92	5.16	3.92	S	5.41	0.26	23.90
SMU9	P24	0-7	1.98	84.00	85.98	7.91	6.11	S	5.95	0.55	27.60
		7-100	1.61	83.33	84.94	8.53	6.53	S	4.83	0.60	27.90
SMU10	P12	0-100	3.16	51.17	54.33	23.16	22.51	SCL	18.41	1.13	42.70
SMU11	P21	0-13	5.05	40.95	46.00	28.03	25.97	SCL	2.55	1.32	45.10
		13-40	4.63	44.66	49.29	25.90	24.81	SCL	4.26	1.23	44.20
		> 40	4.12	38.03	42.15	29.12	28.73	SCL	2.18	1.50	46.60

*S= sandy, SL= sandy loam, SCL= sandy clay loam, and CL= clay loam

TABLE 2. Soil chemical analysis for some representative profiles of soil map units (SMUs) in Bahariya Oasis

SMU	Prof. No	Depth (cm)	Soluble Cations meq L^{-1}				Soluble Anions meq L^{-1}			pH	EC dS m^{-1}	CEC meq/100g	ESP	Gypsum (%)	Available NPK (PPM)			C/N Ratio
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}						N	P	K	
SMU1	P11	0-5	98.90	41.20	194.70	0.18	15.80	143.00	176.18	7.44	31.40	5.03	14.65	3.19	22.20	15.39	107.5	10.26
		5-13	83.40	42.60	161.90	0.11	12.10	131.60	144.31	7.48	25.30	5.68	14.20	7.22	23.90	14.91	116.3	14.95
		13-33	60.30	30.90	122.70	0.06	8.30	103.00	102.66	7.52	19.20	5.91	13.83	6.33	24.70	14.51	121.6	20.61
		33-46	37.10	19.40	75.50	0.02	4.20	60.90	66.92	7.59	11.50	6.42	13.82	7.82	26.90	13.73	132.1	25.58
SMU2	P18	0-3	55.80	52.90	203.10	0.18	5.60	212.40	93.98	8.16	29.80	4.77	14.10	3.02	21.40	15.45	104.0	9.58
		3-19	41.90	42.70	143.20	0.13	4.90	153.20	69.83	8.22	21.30	5.30	14.01	8.68	22.80	15.28	110.0	12.79
		19-40	35.40	28.80	125.60	0.15	2.40	138.60	48.95	8.29	16.70	6.13	13.82	6.32	25.10	14.31	123.0	21.67
		> 40	19.70	18.50	69.80	0.03	1.50	79.10	27.43	8.33	9.90	6.65	13.81	6.36	27.50	13.63	134.0	26.74
SMU3	P28	0-3	27.20	13.40	68.20	0.17	1.70	51.90	55.37	7.51	17.10	11.18	12.10	4.98	40.50	10.17	175.0	16.80
		3-13	21.90	13.80	52.30	0.13	1.50	44.30	42.33	7.58	14.20	11.42	12.01	6.97	41.40	9.74	181.0	18.84
		13-56	13.60	8.40	34.90	0.10	1.10	26.30	29.60	7.63	9.80	12.71	12.00	5.23	44.60	8.65	194.0	21.80
SMU4	P22	0-12	87.20	60.30	302.30	0.22	4.30	319.30	126.42	8.73	42.60	18.95	12.00	N.D	63.60	2.94	245.0	21.22
		12-60	69.80	47.90	245.10	0.19	3.60	269.20	90.19	8.79	35.10	20.05	11.89	N.D	66.80	2.37	264.0	24.02
SMU5	P2	0-3	75.90	37.60	265.30	0.16	15.20	294.30	69.46	7.84	35.90	18.20	13.77	N.D	61.20	3.53	237.5	21.37
		3-35	65.80	29.90	218.40	0.12	9.70	252.10	52.42	7.91	29.90	18.62	12.85	4.15	62.70	3.12	241.2	23.42
SMU6	P27	0-3	66.20	31.50	138.10	0.21	2.60	114.00	119.41	7.12	22.30	7.19	11.97	4.12	29.30	13.25	139.0	8.24
		3-16	47.10	25.80	97.90	0.16	1.90	79.60	89.46	7.23	15.90	8.72	11.84	8.16	33.10	12.19	150.0	12.02
		16-41	35.80	21.30	75.80	0.11	1.40	58.40	73.21	7.25	12.80	14.88	11.82	6.95	49.90	6.58	214.0	27.75
		> 41	22.70	16.60	49.60	0.08	1.20	39.10	48.68	7.31	7.70	17.59	11.79	6.89	59.30	3.96	234.0	38.86
SMU7	P17	0-100	29.70	29.40	101.90	0.10	3.50	113.60	44.00	7.94	14.90	2.71	13.65	N.D	15.30	18.17	78.0	13.57
SMU8	P30	0-18	36.10	23.10	87.60	0.22	2.80	69.50	74.72	7.88	23.10	4.05	11.90	N.D	18.90	16.16	94.0	11.14
		18-45	24.40	15.60	56.90	0.14	2.60	45.70	48.74	7.95	15.30	4.28	11.99	6.14	19.70	15.77	99.0	13.74
SMU9	P24	0-7	26.10	15.10	49.70	0.09	1.90	41.20	47.89	7.42	7.90	8.05	12.13	2.14	31.30	12.68	145.0	15.23
		7-100	18.50	9.20	36.20	0.06	1.40	25.20	37.36	7.45	5.70	8.51	12.05	2.83	32.60	12.33	149.0	19.38
SMU10	P12	0-100	7.30	4.50	28.20	0.01	2.80	30.60	6.61	8.22	3.20	16.12	13.75	N.D	53.10	5.32	225.4	21.90
SMU11	P21	0-13	14.80	8.10	30.10	0.05	2.30	22.10	28.65	7.66	4.90	17.84	12.00	3.11	60.40	3.87	236.0	19.68
		13-40	10.90	7.20	20.90	0.04	2.60	17.30	19.14	7.72	3.20	14.35	11.99	4.72	57.80	4.38	233.0	19.86
		> 40	7.60	4.60	15.80	0.03	2.90	12.10	13.03	7.76	2.10	19.43	11.85	2.19	64.90	2.56	251.0	26.43

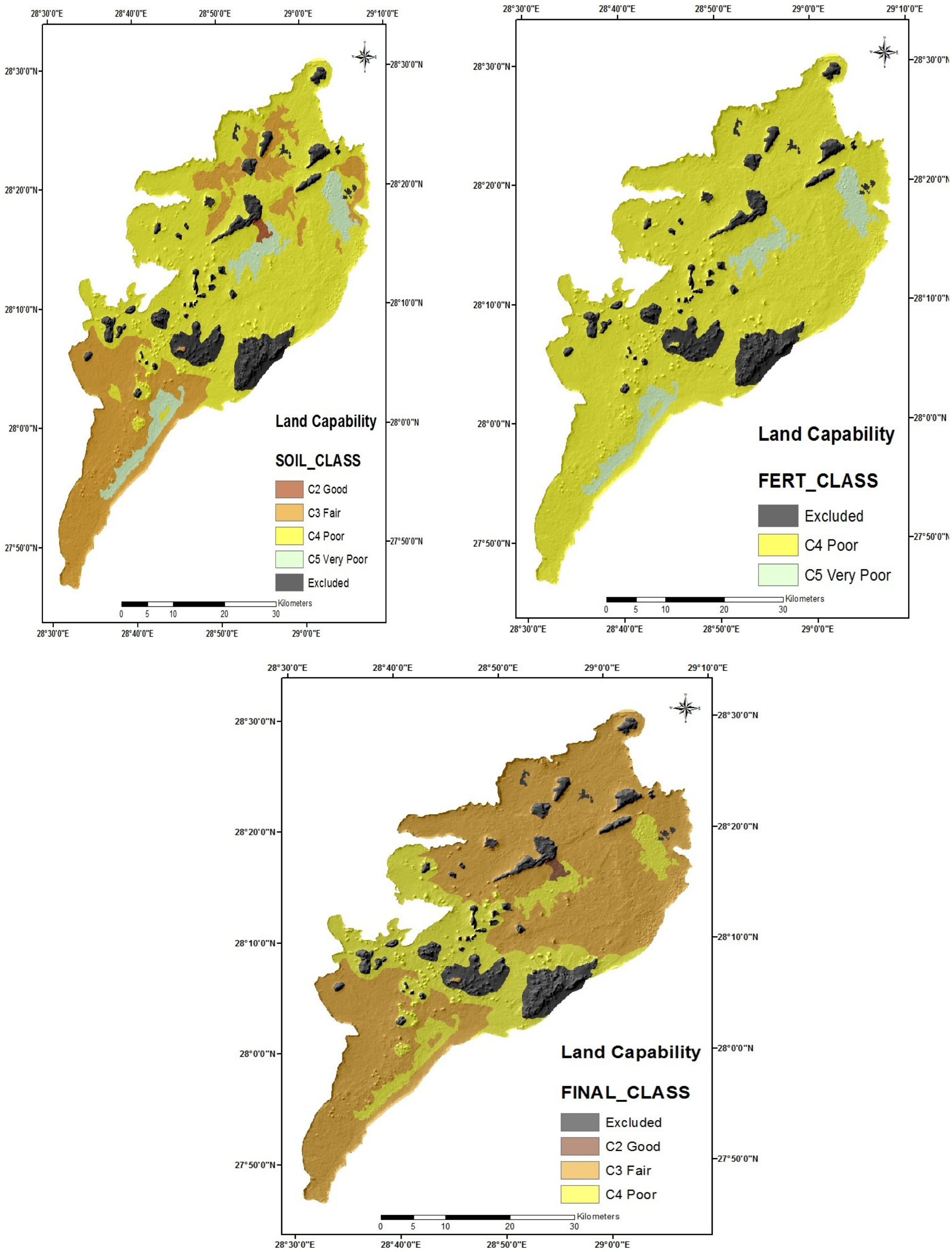

Fig. 3. Spatial distribution of soil index, fertility index, and land capability in Bahariya Oasis

Fertility index

Fertility index was evaluated based on four fertility parameters, which are organic matter (OM) and available nitrogen (N), phosphorous (P), and potassium (K). Soil fertility of the studied soils were located within two classes, which are poor (C4) and very poor (C5) index as illustrated in Fig. 3. Poor soils represent about 84.3% of the studied area, whereas very poor soils represent about 5.8% of the area.

Water index

Water index was evaluated based on the values of sodium (Na^+), chloride (Cl^-), boron, sodium adsorption ratio (SAR), and electrical conductivity (EC) in irrigation water. Water index of the studied area indicates that irrigation water was excellent (C1) in its quality.

Final index

The land capability index was calculated from the above mentioned indices. Soils of the studied area were set in three capability classes, which are good (C2), fair (C3) and poor (C4) as shown in Fig. 3. Land capability degrees ranged between (39.36 to 60.64%). Good soils represent about 0.4 % of the studied area, where fair and poor soils represent about 64.8 and 24.9 %, respectively. Soil index was calculated for each soil map unit as represented in Table 3. According to ASLEarid, the studied area was classified into three capability classes:

1- *Soils with Good (C2) land capability:* This class is represented by only one soil map unit (10). Soils in this class have minor limitations, which require good on going management practices or slightly restrict the range of crops, or both. Soil map unit in this class has fair soil index (64.15%), mostly affected by the lower values of available water and cation exchange capacity (CEC) of these soils. Soil fertility of these soils were also low (soil fertility index was 43.99 %), mainly due to lower content of soil organic matter and available phosphorus. These limitations are considered as non-permanent limitations. Accordingly, these soils need slightly good management practices to improve its current situation.

2- *Soils with fair (C3) land capability:* This class included most of soil map units in the studied area; these units are 2, 3, 4, 5, 6, 8, 9 and 11. Soils in this class have limitations that require moderately intensive management practices or moderately restrict the range of crops, or both. These soil map units have low fertility index, which varied from (22.39 - 35.89%). They also have poor soil index (21.49 - 38.96%) for SMUs (2, 4, 6 and 11) and fair soil index (40.04 - 51.22%) for SUMs (3, 5, 8 and 9). However, all of these SMUs don't have permanent limitations, so the current capability of these SMUs can be changed to be "Good" with moderately intensive management practices.

3-*Soils with poor (C4) land capability:* This class included soil map units 1 and 7. Soils in this class have limitations that require special management practices or severely restrict the range of crops, or both. These soil map units have some limitations such as texture, salinity, available water, hydraulic conductivity and fertility because it has low soil index (18.85 - 26.67%) and fertility index (15.85 - 23.01%). These soils require good and proper management. However, the limitations in these soil map unit are non-permanent. Therefore, with good management practices, the class of these soil map units could be improved to be "Fair or Good".

Land suitability classification

ASLEarid software was used as a Decision Support System (DSS) based on the dominant soil characteristics that limit the soil suitability for certain land use. Soil suitability of a soil component (unit) was assessed through the maximum limitation method. Soil suitability was assessed for twenty traditional crops, which were classified into three categories as follows:
Field crops (wheat, barely, peanut, maize, faba bean, sugar beet, sunflower, and alfalfa),
Vegetable crops (tomato, watermelon, onion, pea, pepper, and potato) ,
Fruit trees (date palm, olive, grape, fig, citrus, and pear).

Spatial distribution of land suitability for each crop was represented using the ArcGIS software as illustrated in Fig. 4 to 8.

SMU1: Data in Tables 4 to 6 show that this map unit is moderately suitable (S2) for tomato and potato. It is marginally suitable (S3) for wheat, barely peanut, sugar beet, alfalfa and watermelon; conditionally suitable (S4) for maize, faba bean, sun flower, onion, pea, and pepper; and actually unsuitable (NS2) for date palm, olive, grape, fig, citrus and pear. Non-suitable area(s) was due to soil depth restrictions, which can be modified through management practices. Digging pits under fruit trees is one of the common practices in these areas.

SMU2: This map unit is moderately suitable (S2) for tomato and potato; marginally suitable (S3) for wheat, barely peanut, sugar beet, maize, alfalfa and watermelon; and conditionally suitable (S4) for faba bean, sun flower, onion, pea and pepper. Also, it is actually unsuitable for date palm, olive, grape, fig, citrus and pear.

SMU3: This map unit is moderately suitable (S2) for wheat, barely, maize, faba bean, sugar beet, alfalfa, watermelon, onion, pea and pepper, and marginally suitable (S3) for peanut, sunflower, tomato, potato and grape. On the other hand, it is actually unsuitable (NS2) for date palm, olive, fig, citrus and pear.

SMU4: This map unit is marginally suitable (S3) for peanut, maize, faba bean, sunflower, tomato, watermelon, pea, pepper, potato and grape; and conditionally suitable (S4) for wheat, barely, sugar beet, alfalfa and onion. It is also actually unsuitable (NS2) for date palm, olive, fig, citrus and pear.

SMU5: This map unit is marginally suitable (S3) for wheat, barely, maize, faba bean, sugar beet, alfalfa, watermelon, onion, pea, and pepper; whereas it is conditionally suitable (S4) for peanut, sunflower, tomato, and potato. This unit is also actually unsuitable (NS2) for date palm, olive, grape, fig, citrus, and pear.

SMU6: This map unit is moderately suitable (S2) for wheat, barely, maize, faba bean, sugar beet, sunflower, alfalfa, watermelon, onion, pea, and pepper; and it is marginally suitable (S3) for peanut, tomato, potato and grape. It is also actually unsuitable (NS2) for date palm, olive, fig, citrus and pear.

SMU7: This map unit is marginally suitable (S3) for wheat, barely, sugar beet, sunflower, alfalfa, date palm, olive and fig; whereas it is conditionally suitable (S4) for peanut, maize, faba bean, tomato, watermelon, onion, pea, pepper, potato, grape, citrus and pear.

SMU8: This map unit is moderately suitable (S2) for tomato; marginally suitable (S3) for wheat, barely, peanut, maize, sugar beet, alfalfa watermelon, pepper and potato; and conditionally suitable (S4) for faba bean, sugar beet, sunflower, onion, and pea. Soil in this unit is also actually unsuitable (NS2) for date palm, olive, grape, fig, citrus, and pear.

TABLE 3. and capability classes in the studied area

Physiographic Unit		Profile No.	Soil Taxonomy (Sub-great group)	Capability Classes
Plains		24	Typic Torripsamments	C3 (Fair)
		26	Typic Torripsamments	C3 (Fair)
Depression Floor	Lowland	3	Typic Quartzipsamments	C4 (Poor)
		5	Typic Torripsamments	C3 (Fair)
		6	Typic Aquisalids	C3 (Fair)
		9	Typic Quartzipsamments	C4 (Poor)
		22	Typic Aquisalids	C3 (Fair)
		23	Typic Quartzipsamments	C4 (Poor)
		29	Typic Torripsamments	C3 (Fair)
	Moderately High land	1	Lithic Haplosalids	C3 (Fair)
		2	Lithic Haplosalids	C3 (Fair)
		4	Typic Haplogypsids	C3 (Fair)
		7	Typic Aquisalids	C3 (Fair)
		10	Lithic Haplogypsids	C3 (Fair)
		11	Lithic Calcigypsids	C4 (Poor)
		12	Typic Torrifluvents	C2 (Good)
		13	Typic Quartzipsamments	C4 (Poor)
		14	Lithic Torripsamments	C3 (Fair)
		15	Lithic Calcigypsids	C4 (Poor)
		16	Lithic Calcigypsids	C4 (Poor)
		17	Typic Quartzipsamments	C3 (Fair)
		18	Lithic Haplogypsids	C3 (Fair)
		21	Typic Torriorthents	C3 (Fair)
		25	Typic Haplogypsids	C3 (Fair)
		27	Typic Gypsiargids	C3 (Fair)
		28	Typic Haplogypsids	C3 (Fair)
		30	Lithic Haplogypsids	C3 (Fair)
		31	Lithic Haplogypsids	C3 (Fair)
	High land	19	Lithic Calcigypsids	C4 (Poor)
		20	Lithic Calcigypsids	C4 (Poor)
Pediment		8	Lithic Calcigypsids	C4 (Poor)

C1: Excellent, **C2:** Good, **C3:** Fair, **C4:** Poor, **C5:** Very poor, **C6:** Non-agriculture .

SMU9: This map unit is highly suitable (S1) for tomato, date palm and fig; moderately suitable (S2) for peanut, maize, faba bean, sunflower, watermelon, pea, pepper, potato, olive, grape, and citrus; and marginally suitable (S3) for wheat, barely, sugar beet, alfalfa, onion, and pear.

SMU10: This map unit is highly suitable (S1) for wheat, sunflower, alfalfa, and watermelon; and moderately suitable (S2) for barely, maize, faba bean, sugar beet, tomato, onion, pea, pepper, date palm, and pear. Soils in this unit are marginally suitable (S3) for peanut, potato, olive, grape, fig, and citrus.

SMU11: This map unit is marginally suitable (S3) for wheat, barely, peanut, maize, faba bean, sugar beet, alfalfa, tomato, watermelon, onion, pea, pepper, potato, date palm, olive, fig and pear; whereas, it is conditionally suitable (S4) for sunflower, grape and pear.

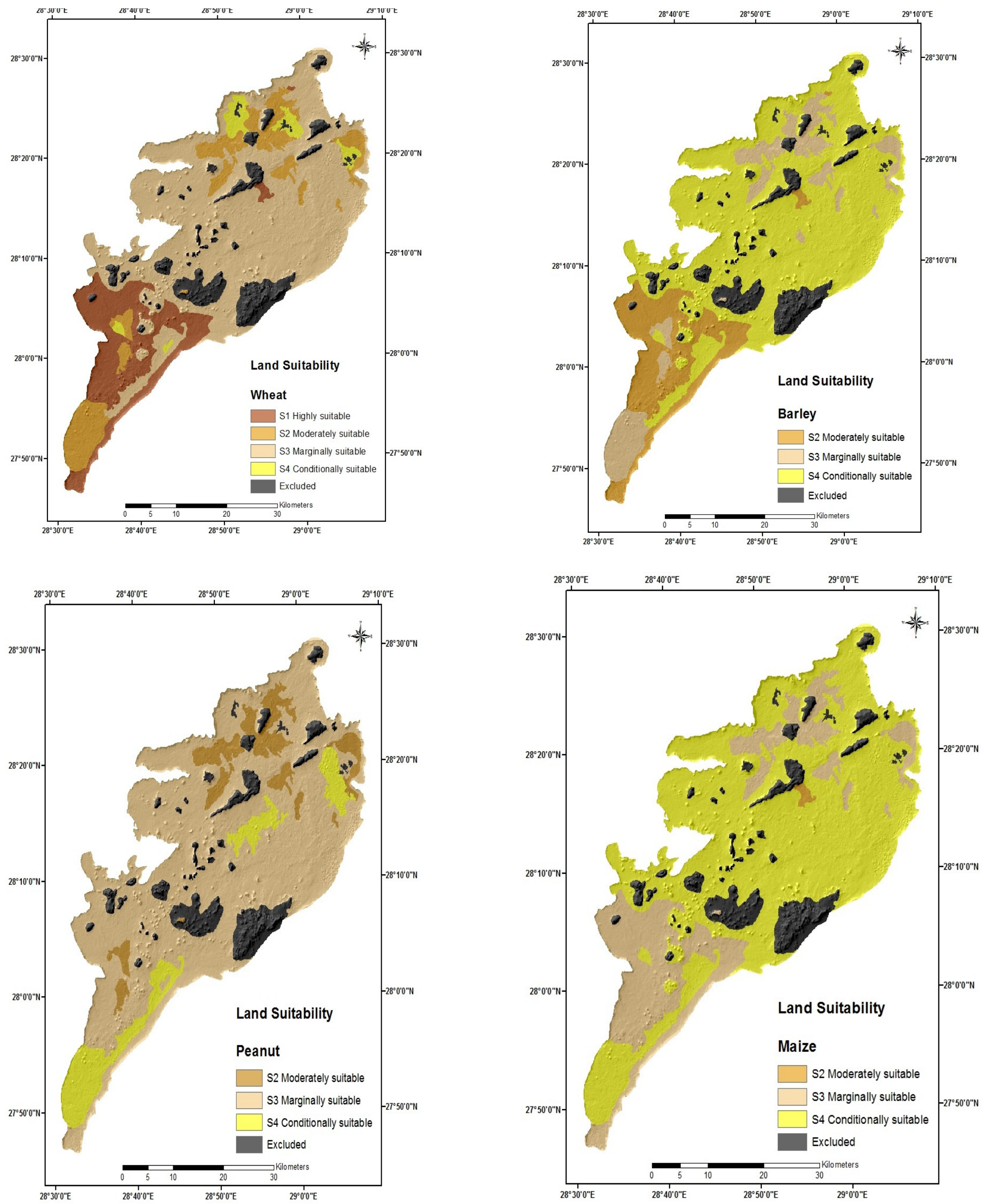

Fig. 4. Suitability map for wheat, barley, peanut and Maize in Bahariya Oasis

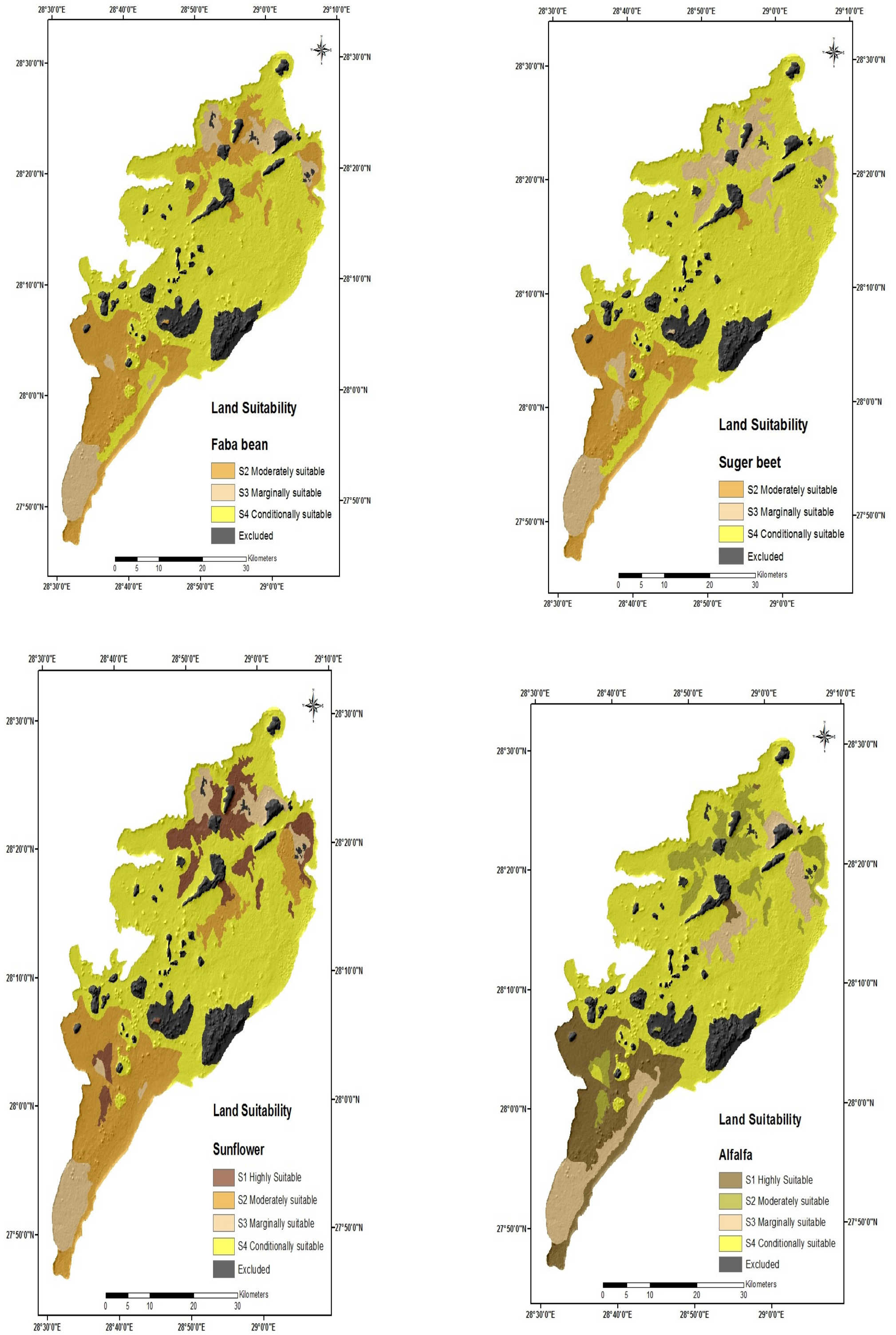

Fig. 5. Suitability map for faba bean, sugar beet, sunflower and alfalfa in Bahariya Oasis

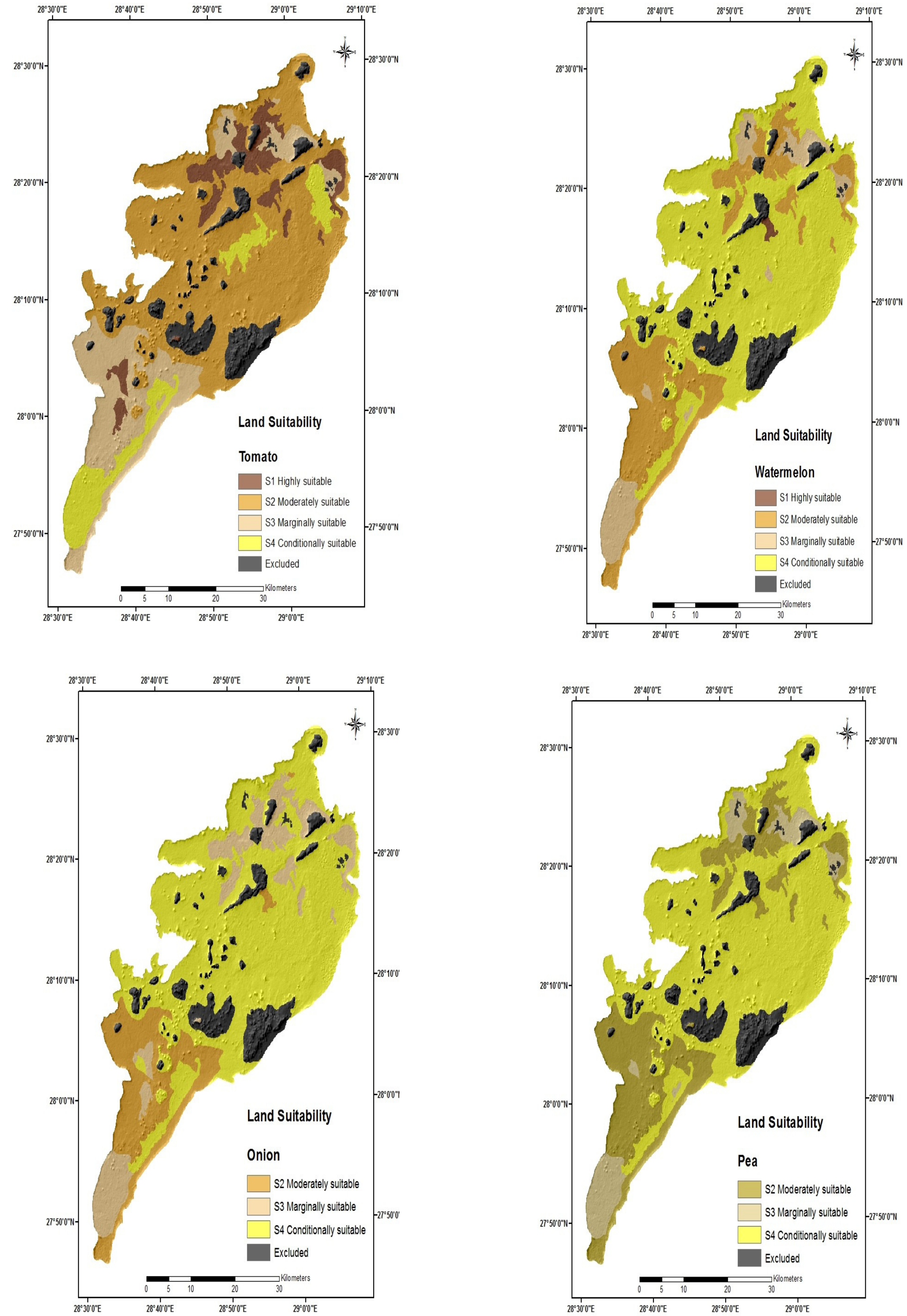

Fig. 6. Suitability map for Tomato, watermelon, onion, and pea in Bahariya Oasis.

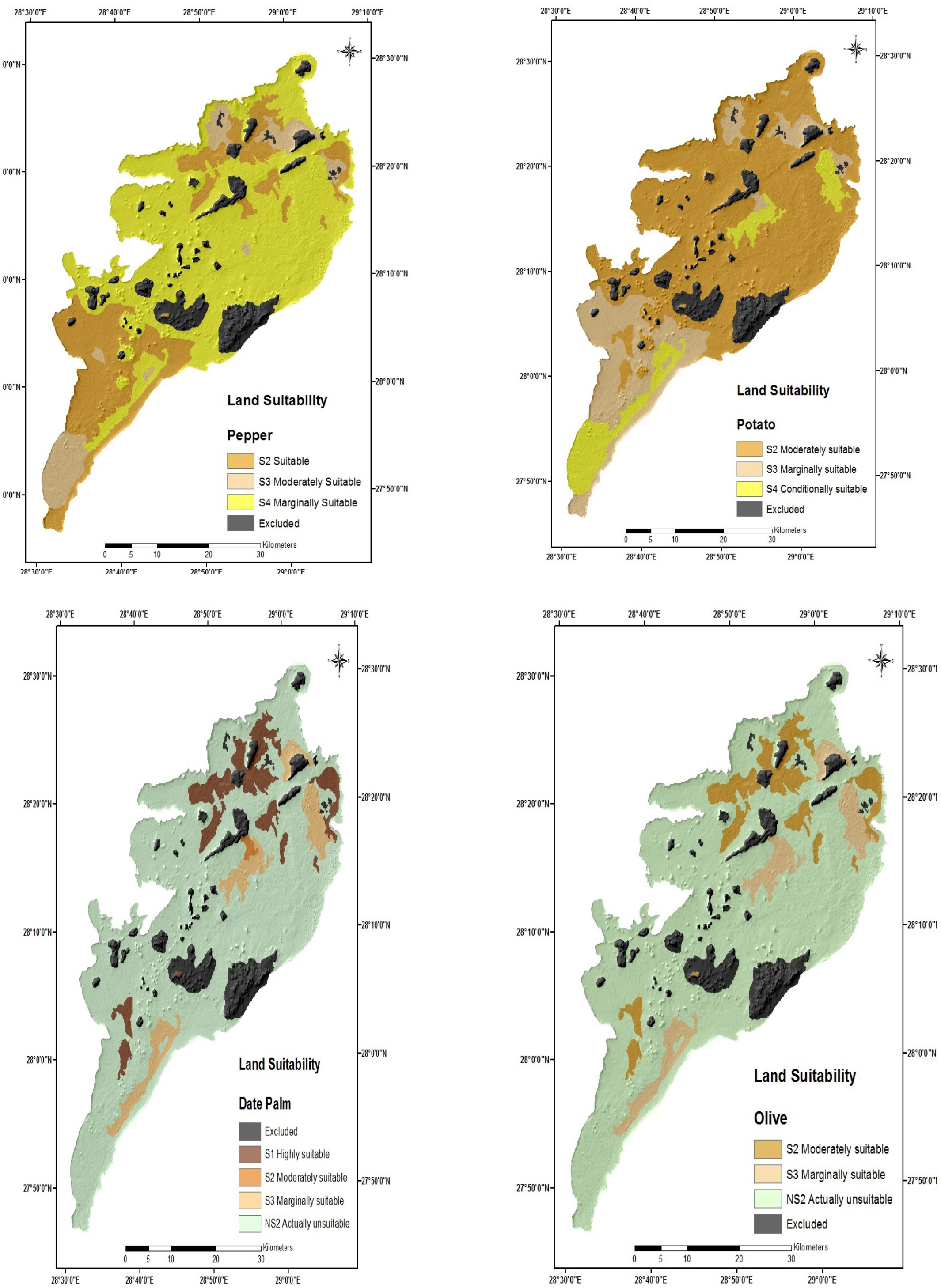

Fig. 7. Suitability map for pepper, potato, date palm, and olive in Bahariya Oasis

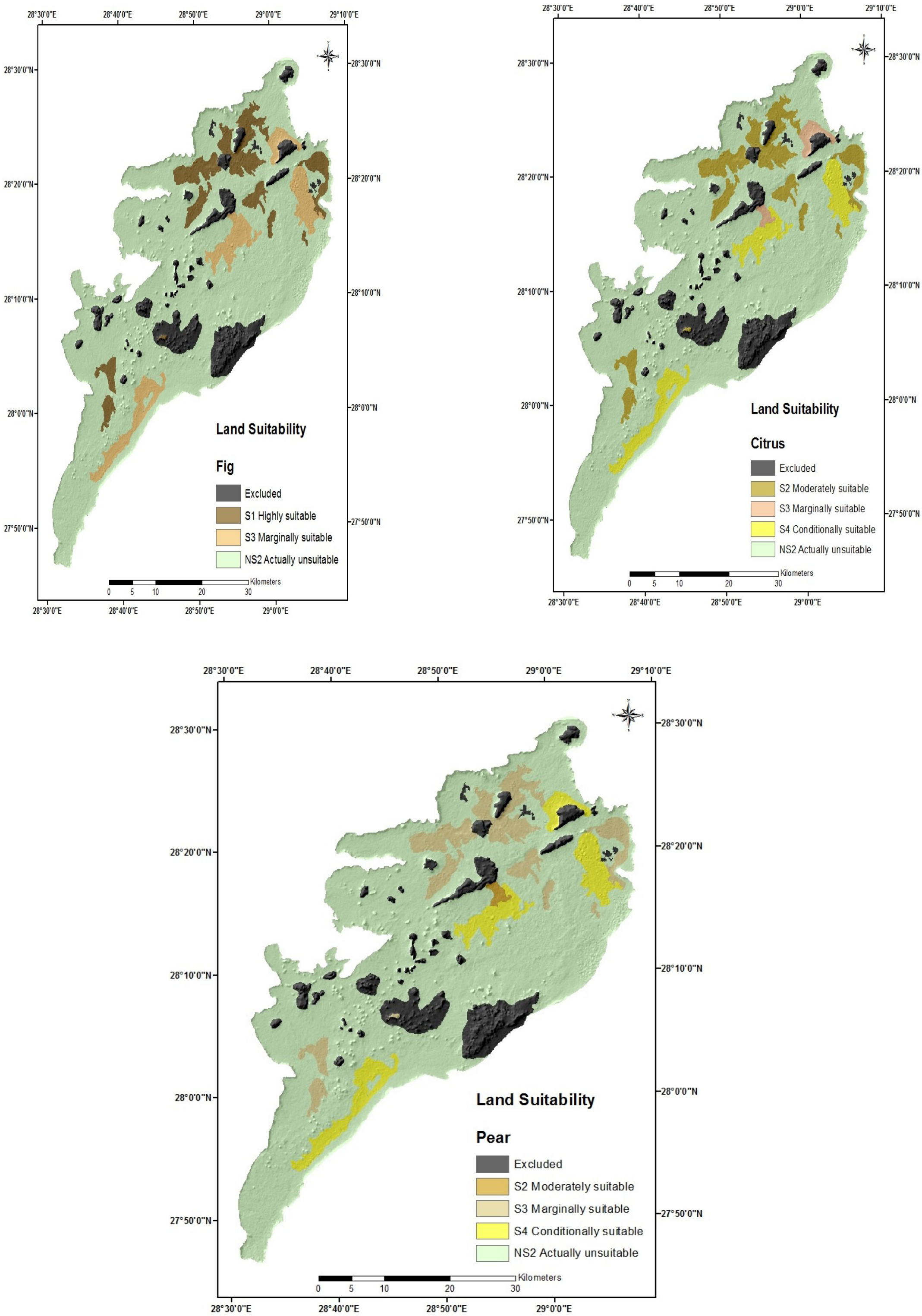

Fig. 8. Suitability map for fig, citrus, and pear in Bahariya Oasis

Conclusion

It could be concluded that the Agriculture Land Evaluation System for arid and semi-arid region (ASLEarid) was very effective in evaluating land capability and suitability in Bahariya Oasis. According to that model, soils in the studied area were set in three capability classes, which are good (C2), fair (C3) and poor (C4). Poor land capabilities were mainly associated with poor soil texture, high salinity, low available water, high hydraulic conductivity and low fertility.

Land suitability for the selected field crops and vegetables varied from highly suitable (S1) to conditionally suitable (S4). On the other hand, land suitability for the selected fruit trees ranged from highly suitable (S1) to actually unsuitable (NS2). Non-suitable areas for fruit trees were mainly due to soil depth restrictions and high salinity, which can be modified through the proper land management practices.

In conclusion, soils in Bahariya Oasis could have a promising future for agricultural expansion projects, where soil limitations for crop production in Bahariya Oasis are none - permanent. These limitations can be improved if both suitable reclamation methods and appropriate management practices were applied.

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تطوير خرائط القدرة الأنتاجية والملائمة للواحات البحرية في مصر

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تعتبر التربة في الواحات البحرية واحة واعدة لمشاريع استصلاح الأراضي بسبب موقعها المتميز ووفرة المياه الجوفية اللازمة لري المحاصيل. ويهدف هذا العمل الى تقييم القدرة الأنتاجيةland capability لأراضى الواحات البحرية وكذلك تقييم مدى ملائمتهاland suitability لبعض المحاصيل. وتبعا لذلك، تم حفر ٣١ قطاع أراضى وتسجيل احداثياتها وتوصيفها فى الحقل وتصنيفها. كما تم جمع ٦٨ عينة تربة من هذه القطاعات وتحليلها للتعرف على لخواصها الفيزيائية والكيميائية. كما تم أيضا جمع عينات مياه من آبار الري وتحليل خواصها الكيميائية. وتم تقييم الأراضي باستخدام نظام تقييم الأراضى الزراعة للمناطق الجافة وشبه الجافة (ASLEarid).

دلت النتائج على أن التربة في الواحات البحرية تقع في ثلاث فئات تبعا لقدرتها الأنتاجية هي جيدة (C2)، ومعتدلة (C3) وضعيفة (C4). وكانت الفئة الأولى C2 ممثلة بوحدة خريطة ارضية واحدة فقط (SMU10). والأراضى فى هذه الرتبة ذات مؤشر تربة (SI) معتدل ومؤشر خصوبة تربة (SFI) منخفض. وتتميز بوجود معوقات قليلة والتي تتطلب عمليات ادارة تربة جيدة ومستمرة. وتضم الفئة الثانية C3 فئة معظم الوحدات الأرضية SMUs المدروسة (٢، ٣، ٤، ٥، ٦، ٨، ٩ و ١١). ويتراوح مؤشرى SI و SFI لهذه الأراضى بين منخفض ومعتدل. وتحتاج الى عمليات أدارة تربة متوسطة. وتضم الفئة الثالثة C4 الرتب الأرضية ١ و٧. والأراضى فى هذه الفئة ذات مؤشرات SI وSFI منخفضة. وتوجد لديها معوقات تحتاج الى عمليات إدارة خاصة. وقد وجد ان القدرات الأرض المنخفضة تترتبط بضعف قوام التربة والملوحة العالية وقلة الماء الميسر والتوصيل الهيدروليكي العالى وانخفاض الخصوبة.

وأظهرت نتائج ملائمة التربة للمحاصيل الحقلية المختارة أن القمح وعباد الشمس والبرسيم كانت عالية جدا S1 إلى مشروطة الملائمة S4 وكان الشعير والفول السوداني والذرة والفول البلدى وبنجر السكر متوسطة S2 إلى مشروطة الملائمة S4 في جميع الوحدات الأرضية SMUs. ومن ناحية أخرى، أظهرت محاصيل الخضر المختارة ان الطماطم والبطيخ كانت عالية S1 الى مشروطة الملائمة S4 وكان البصل والبسلة والفلفل والبطاطس متوسطة S2 إلى مشروطة الملائمة S4 في جميع الـ SMUs. وتتراوحت ملائمة التربة لاشجار الفاكهة المختارة بين عالية جدا S1 وغير ملائمة NS2 بالنسبة لنخيل البلح والتين، في حين تراوحت بين متوسطة S2 الى غير ملائمة فعلا NS2 بالنسبة للزيتون والعنب والحمضيات والكمثرى. وترجع معظم المناطق غير الملائمة الى القيود المفروضة على عمق التربة و درجة الملوحة والتى التي يمكن تعديلها من خلال عمليات إدارة الأراضي المناسبة.

وعموما، فإن معوقات التربة بالنسبة لإنتاج المحاصيل في الواحات البحرية الواحات هى معوقات غير دائمة ومعظم هذه المعوقات يمكن تحسينها من خلال عمليات الإدارة السليمة.