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Land Resources Evaluation for Sustainable Agriculture in El-Qusiya Area, Assiut, Egypt

Mohamed E. Fadl[1*] and Yasser. A. Sayed[2]

[1]*Division of Scientific Training and Continuous Studies, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt*

[2]*Soils and Water Science Department, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt.*

INCREASING the cultivated areas in Egypt is necessary to achieve over-growing population sufficiency. However, accurate land evaluation is great concern to achieve sustainable agricultural production. The current study aimed at evaluating land capability and suitability in El-Qusiya City, Assiut Governorate, Egypt using Remote Sensing (RS) and Geographic Information Systems (GIS) techniques. The soils of the study area belonged two land capability classes according to Storie index; fair (Grade 3) that occupied an area about 53.97km^2 (56.95%) of the total study area, and poor (Grade 4) that occupied an area about 40.79km^2 (43.046%) of the total study area with slope and other soil limitation factors, and two suitability class according to Sys and Verheye system; classes marginal suitable (S3) that occupied an area about 65.85 km^2 (68.93%) of the total study area with severe limitations and presently not suitable (N1) that occupied an area about 28.91km^2 (30.26%) of the total study area with very severe limitations that can be corrected. The Cervatana model showed that land capability classes of the study area are good (S2)) that occupied an area about 62.8 km^2 of the total study area, moderate (S3) that occupied an area about 3.05 km^2 of the total study area and marginal (N) that occupied an area about 28.91 km^2 of the total study area with limiting factors of soil (i), erosion risks (r) and bioclimatic deficit (b). The Almagra model for land suitability appraisal of different crops (Wheat, Maize, Watermelon, Potato, Soybean, Cotton, Sunflower, Sugar beet, Alfalfa, Peach, Citrus, and Olive) evaluation illustrated that the area belonged to suitability classes of high suitable (S2), moderate suitable (S3), marginally suitable (S4) and not suitable (S5). with limitation factors of texture (t), drainage (d), carbonate (c), salinity (s), sodium saturation (a) and profile development (g). The most obvious limiting factors for the selected crops were salinity and sodium saturation.

Keywords: Land evaluation, Land capability and suitability, Sustainable agriculture.

Introduction

Overpopulation and changing human needs play an important role in demanding more different land uses, wherefore land assessment depends mainly on soil, vegetation, climate and other land survey characteristics in terms of requirements for alternative types of land use. Soil capability is important for land physical ability to preserve land uses and management practices domain in long term without soil, air, and water resources degradation (Dent and Young 1981; Central West CMA, 2008; Eid et al., 2013). Washout to land management according to their risk of resource deteriorates both inside and outside the land unit, resulting in a decrease in the natural ecosystem values and agricultural productivity (Lawrie et al., 2007). Land suitability assessment is predicting soil potentiality and ability to crop production in a sustainable mechanism and identification of limiting factors that determine agricultural production to enables decision-makers to improve crop productivity requirements to assure sustainable agricultural uses without significant deterioration causing for land quality, which is reflected in the increase in land productivity (Shalaby et al. 2017; Soliman 2016). Land assessment for land use planning and sustainable soil developments is depending on land environmental possibilities, soil limiting factors and the ingrained suitability of land units

*Corresponding Author: E-mail: Adhamnarss@yahoo.com

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for supporting crops suitability, that can be carried out using land assessment through automatize systems such as MicroLEIS models, Cervatana & Almagra, (Yousif, 2019). MicroLIES-Almagra model was used to assess the land suitability for different crops in west of Dakhla oasis, Egypt. Abd El-Aziz (2018) used MicroLEIS models to evaluate land capability and suitability of Tushka area for crop production and identify the factors that hinder the cultivation process. GIS model and ASLE software integration were executed for land capability and suitability, meanwhile incorporating aspects of chemical and physical soils, fertility and the environment is necessary to assessing soil quality to initiating and achieve more suitable land use planning (Abuzaid and Fadl, 2016; Abuzaid et al., 2020). El-Desoky and Sayed (2019) using Riquier Land Productivity Index (RLPI) to assess the land productivity of Edfu area, Aswan, Egypt based on land resources, soil properties using remote sensing and geographic information system (GIS) techniques. GIS and remote sensing systems is an useful appliance tools for devices to processing large amounts of spatial data of land resources, display the analyze data manipulate and storage capabilities in different scales and formats and providing accessible and accurate land assessments information (Abuzaid and Fadl 2018; Megahed and Farrag 2019; Farrag et al., 2019).

The current study was carried out on the soils of west El-Qusiya area, Assiut, Egypt to assess their capability and crop suitability based on soil physiochemical characteristics using survey and laboratory data in accordance with GIS and remote sensing techniques. Such study would enable decision-makers to improve land-use planning to achieve sustainable agriculture development.

Material and methods

Location of the investigated area

The investigated area located in west of El-Qusiya City, Assiut Governorate between 30° 43' 00" and 30° 49' 00" E and 27° 18' 00" and 27° 24' 00" N, covering an area of 40.17 km^2, (4017 hectares), (Fig. 1). The climate of the study area represents Egypt arid belt that is characterized by cold winter, long dry and very hot summer with average temperatures are normally between 11.9 and 30.7 °C with mean of 21.3°C in common, very low rainfall (2.9 mm/year), and highly evapotranspiration (Egyptian Meteorological Authority, 2017). The study area is distinguished by *Torric* soil moisture and *Thermic* temperature regime (Soil Survey Staff, 2014a).

Remote sensing and GIS processing

Landsat 8 satellite image (Path 176, Row 41, date acquired , 2020-01-11) with image resolution of 30 m) and a digital elevation model (DEM) of Shuttle Radar Topography Mission (SRTM), were used in the current study. A digital image of processing the Landsat 8 image was performed using ENVI 5.1 software (ITT, 2017), including radiometric correction, enhancement, classification (unsupervised; ISO DAT classifier, and supervised; maximum likelihood). On the light of the classified image and DEM, the geometric units were extracted according to Zinck and Valenzuela (1990). Maps (Location, geomorphic unit, land capability, and suitability) were produced using ArcGIS 10.1 software (ESRI, 2014).

Field and laboratory works

Ten geo-referenced soil profiles representing the geomorphic units were dug to a depth of 150 cm or to lithic contact (Fig. 2). They were described according to FAO (2007) and soils samples were collected from different horizons. The soil samples were analyzed in the laboratory using standard methods of Soil Survey Staff (2014b).

Land evaluation

Land capability and crop suitability: Parametric approach

Land capability using Storie index (2008)

Storie index is an acceptable and widely known soil evaluation for land use and productivity method worldwide. Storie index evaluates land capability by following four properties: A, B, C, and X that determined with a score ranging from 0 to 100% for each factor according to (O'GEEN, 2008). The capability classes were calculated according to Storie index classification method as the following formula:

$$\text{Storie index rating} = [(A/100) \times (B/100) \times (C/100) \times (X/100)] \times 100$$

where:

A: Soil physical properties including soil profile depth (cm), B: soil texture, C: slope and X: other soil factors include; topographic, drainage, fertility, nutrient level, erosion, microrelief, and alkalinity, as shown in Table 1.

Land suitability for irrigated agriculture

This system was proposed by Sys and Verheye (1978) based FAO (1976) framework to calculate land suitability orders and classes depending on soil physical and chemical properties, as shown in Table 2. The suitability classes were calculated according to Sys and Verheye index as the following Equation:

The suitability index

$$(Si) = t \times (w/100) \times (S_1/100) \times (S_2/100) \times (S_3/100) \times (S_4/100) \times (n/100)$$

where: t: topography, w: wetness, S_1: soil texture, S_2: soil depth, S_3: $CaCO_3$, S_4: gypsum and n: other soil properties including; salinity and sodicity.

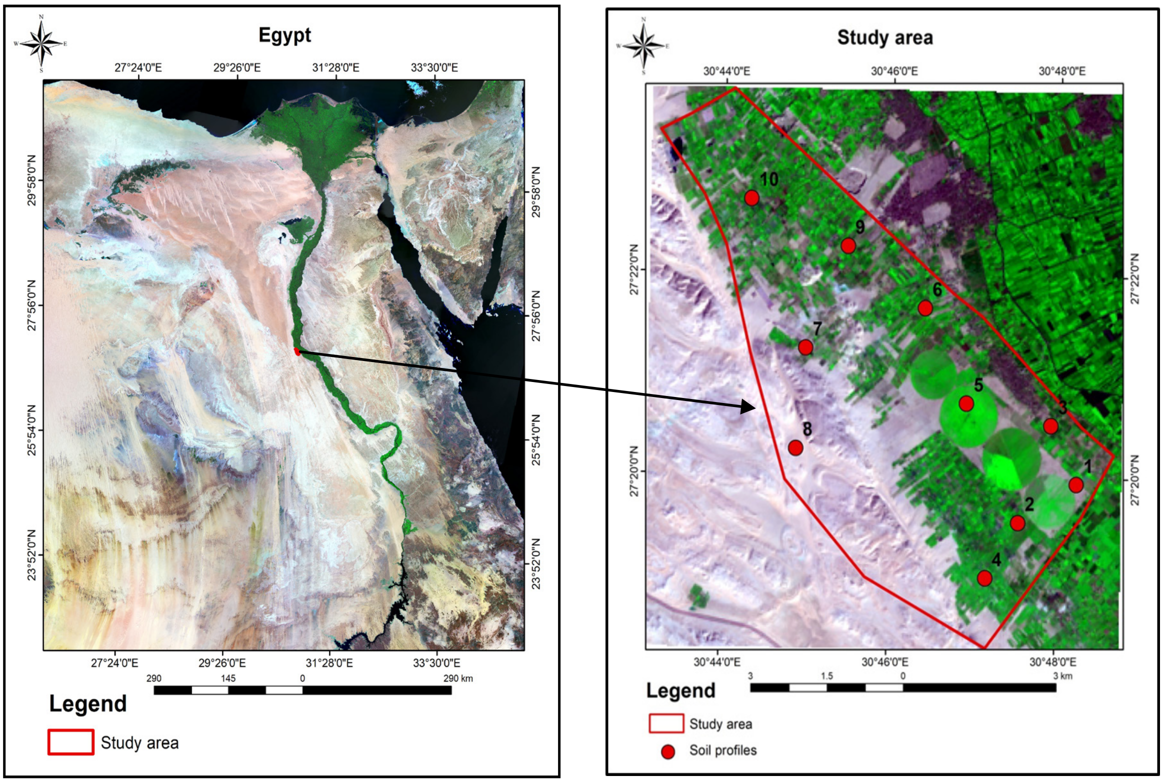

Fig. 1. Location map of the studied area

TABLE 1. Capability classes according to Storie index (O'GEEN, 2008)

Soil factors	Soil properties	Capability classes	Capability rate %
A	Physical properties	Grade 1 (Excellent)	80-100
B	Soil texture	Grade 2 (Good)	60-79
C	Slope	Grade 3 (Fair)	40-59
X	Other soil factors	Grade 4 (Poor)	39-20
		Grade 5 (non-agricultural)	< 20

TABLE 2. Land suitability classes using Sys and Verheye (1978)

Suitability classes	Suitability sub classes	Suitability degree	Limitations degree	Rating %
S	S1	High suitable	Without to low limitations	75-100
	S2	Moderate suitable	Moderately limitations	50-75
	S3	Marginal suitable	Severe limitations	25-50
N	N1	Presently not suitable	Very severe limitations that can be corrected	12.5-25
	N2	Not suitable	Very severe limitations that can't be corrected	<12.5

Land capability and suitability tools

The microcomputer land evaluation information system (MicroLEIS DSS) is a decision support and land evaluation system for agricultural soil protection with particular reference to the Mediterranean countries (De la Rosa et al., 2004). The most commonly used models within this system are Cervatana model and Almagra model.

General land capability (Cervatana model)

This model works interactively to compare the soil properties of the geomorphic unit to be evaluated with the capability class according to the general criteria for soil evaluation (FAO, 1976). Table 3 showed the capability classes and limitations factors were used in Cervatana model.

Agricultural soil suitability MicroLEIS (Almagra model)

This model use physical-chemical evaluation of soil characteristics or conditions for crop development productivity. This automated method for soil suitability was used to identifying crops suitability using soil characteristics and growth requirements such as depth (p), texture (t), sodium saturation (a), carbonate (c), drainage (d) salinity (s) and profile development (g) matching for the different crops. The Almagra model suitability classes, limitations, and soil factors are shown in Table 4. This study full methodology was represented in Fig. 2.

Results and Discussion

Geomorphic units

Geomorphic units was identified throughout satellite image and DTM interpreting methods and field study that afford the reality to the ground observation which are considered as advanced techniques. Satellite image interpretation and field study indicated that, the study area represent three main landform units and four subunits as follows: 1) River terraces (which divided into four mapping unit i.e. recent river terraces, high, moderate and low old river terraces); 2) Overflow basin and 3) Plateau, that respectively to be inputted in the Arc GIS 10.1 software for mapping (Fig. 3). The total area of these geomorphological units are shown in Table 5.

TABLE 3. Capability classes and limitations factors based on MicroLEIS (Cervatana model)

Suitability classes	Suitability definition	Limitations density	Soil factors
S1	Excellent	None	Slope (t)
S2	Good	Slight	Soil (i)
S3	Moderate	Moderate	Erosion risks (r)
N	Marginal	Severe	Bioclimatic deficit (b)

TABLE 4. Almagra model suitability classes, limitations and soil factors

Suitability classes	Limitation	Soil factor
Optimum suitable (S1)	None	Useful depth (p)
High suitable (S2)	Slight	Texture (t)
Moderate suitable (S3)	Moderate	Drainage (d)
Marginally suitable (S4)	Severe	Carbonate (c)
		Salinity (s)
Not suitable (S5)	Very severe	Sodium saturation (a)
		Profile development (g)

TABLE 5. Geomorphic unit of the studied soils

No.	Geomorphological units	Code	Area (m^2)	Area (km^2)
1	Recent River Terraces, represented by soil profile No. 1, 3, 5 and 6	RRT	34899091.09	34.90
2	Low Old River Terraces, represented by soil profile No. 2, 9 and 10	ORT	19071926.89	19.07
3	Mod. Old River Terraces. represented by soil profile No. 4	MORT	8828419.80	8.83
4	High Old River Terraces, represented by soil profile No. 7	HORT	3054703.09	3.05
5	Overflow Basin, represented by soil profile No. 8	OVB	28911551.08	28.91
6	Plateau	PL	777174.97	0.78
	Total		95542866.92	95.54

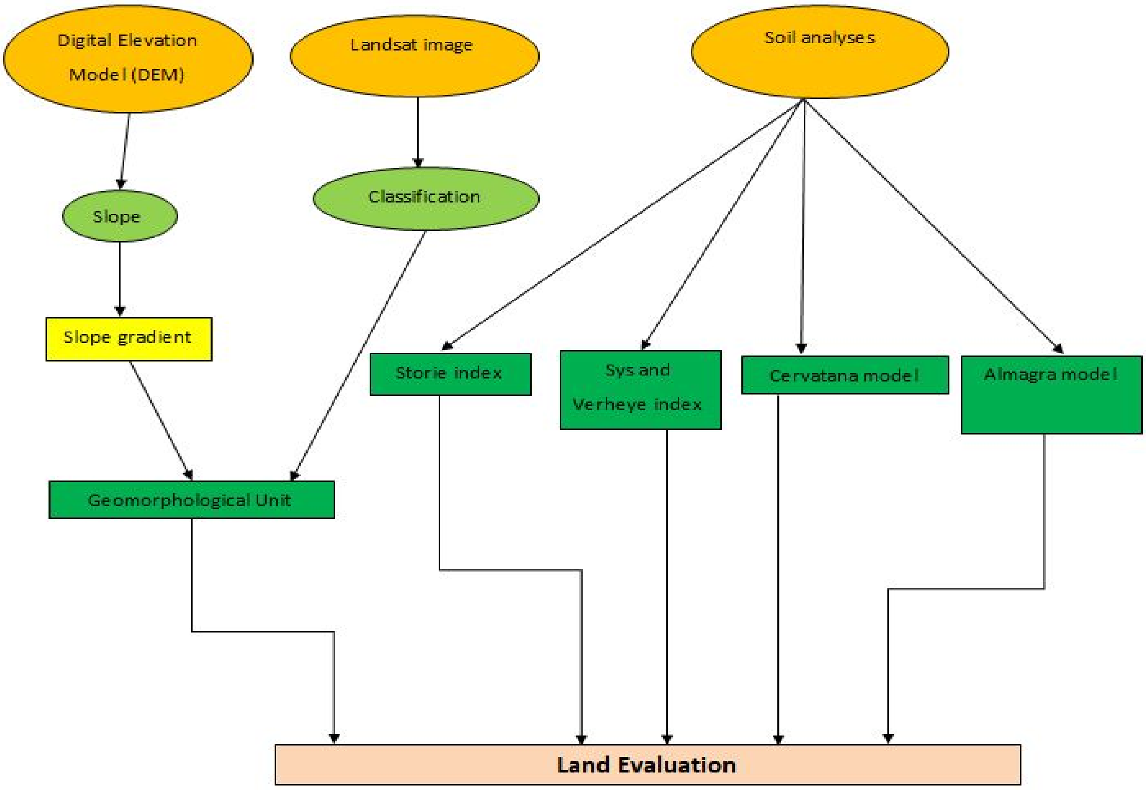

Fig. 2. Land evaluation flowchart methodology

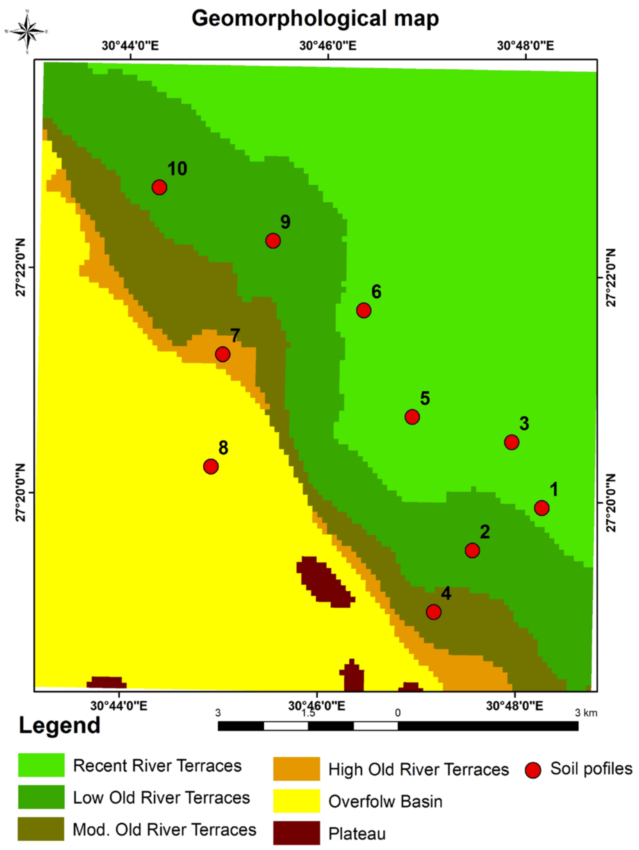

Fig. 3. Geomorphological map of the studied area

Soils properties

Table 6 shows soil properties of the investigated area. The elevation of the study area varied from 48 to 163 m (Fig. 4) and the study area is almost flat (the slope varied from 0.21 to 0.35%) with deep to very deep soil profiles (depth varied from 110 to 150 cm). The soil texture are loamy sand and sandy loam and the gravel content ranged from 2.22 to 12.34 %. The soils are well-drained in all the studied profiles. Soil moisture is one of the most important soil properties for plant growth and sustainability of agricultural ecosystems it ranged from 13.9 to 21.1%. The soil are slightly to moderately alkaline with pH values varied between 8 to 8.6. The soil salinity differed from moderately (EC_e = 2.4 dS/m) to extremely saline (EC_e = 39.4 dS/m). This might be due to salt concentration in soil layers refers to different modes of geological sedimentation through different era. Calcium carbonate ($CaCO_3$) content varied from 50 to 230 g kg^{-1} and the gypsum content differed from 1.1 to 18.4 g kg^{-1}. Organic matter (OM) content in these soils varies from 1.6 to 3.9 g kg^{-1}, due to the gradual reduction of organic residuals. Cations exchange capacity (CEC) varied from 8.1 to 12.6 cmolc kg^{-1}. This value refers to moderate content of clay and organic materials. Exchangeable sodium percentage (ESP) ranged from 21 to 29 indicating sodic soils (ESP > 15).

Land evaluation

The capability index using Storie index

The land capability performed by applying Storie index for different soil units represented by two capability class are fair (Grade 3) that occupied an area about 53.97km^2 (56.95%) of the total study area, and poor (Grade 4) that occupied an area about 40.79km^2 (43.046%) of the total study area with slope and other soil limitation factors as follows in Table 7 and Fig. 5.

The suitability index for irrigation using Sys and Verheye

This system was run to defined land suitability classes of soil units for irrigation purposes based on soil characteristics. By applying Sys and Verheye system, suitability class for irrigation (Ci) representing two classes marginal suitable (S3) that occupied an area about 65.85km^2 (68.93%) of the total study area with severe limitations and presently not suitable (N1) that occupied an area about 28.91km^2 (30.26%) of the total study area with very severe limitations that can be corrected as shown in Table 8 and Fig. 6.

TABLE 6. Some physical and chemical properties of the studied soil profiles

Profile No.	Geomorphological units	Elev. (m)	Slope %	Depth (cm)	Texture class	Gravel %	Drainage class	SM %	pH 1:1	EC_e dS/m	$CaCO_3$ g kg^{-1}	Gypsum g kg^{-1}	O.M %	CEC cmolc kg^{-1}	ESP %
1	Recent River Terraces	57	0.21	150	LS	8.96	Well-drained	15.9	8.3	15.9	180	5.3	0.19	9.8	22
2	Low Old River Terraces	74	0.22	130	LS	6.59	Well drained	17.3	8.3	4.8	230	3.1	0.20	8.1	21
3	Recent River Terraces	48	0.24	150	SL	11.78	Well-drained	17.6	8.0	11.0	50	1.9	0.21	9.0	28
4	Mod. Old River Terraces	92	0.28	130	LS	4.25	Well-drained	15.8	8.0	39.4	110	18.4	0.39	12.5	25
5	Recent River Terraces	57	0.25	150	SL	4.68	Well-drained	13.9	8.1	18.8	60	9.1	0.22	10.9	29
6	Recent River Terraces	59	0.31	150	LS	2.22	Well-drained	18.3	8.6	5.8	80	4.1	0.32	10.7	26
7	High Old River Terraces	99	0.35	130	LS	12.34	Well-drained	21.1	8.1	16.8	110	11.0	0.29	9.7	22
8	Overflow Basin	163	0.24	115	SL	9.30	Well-drained	19.2	8.1	21.9	50	15.5	0.23	12.6	28
9	Low Old River Terraces	72	0.28	140	LS	5.14	Well-drained	20.1	8.6	2.4	80	1.3	0.16	9.4	21
10	Low Old River Terraces	77	0.34	110	LS	7.09	Well-drained	16.2	8.5	3.0	140	1.1	0.33	9.2	21

Elev = Elevation, LS = loamy sand, SL = sandy loam, SM = soil moisture, O.M = organic matter.

TABLE 7. land capability of the study area by Storie index

No.	Capability grade	Capability classes	Area (km^2)	Area (%)
1	Grade 3	Fair	53.97	56.954
2	Grade 4	Poor	40.79	43.046
3	Plateau	Plateau	0.78	0.82
	Total		95.543	100

TABLE 8. Suitability classes of the studied soil profiles using Sys and Verheye

Suitability classes	Suitability sub classes	Suitability degree	Limitations degree	Area (km^2)	Area %
S	S3	Marginal suitable	Severe limitations	65.85	68.93
N	N1	Presently not suitable	Very severe limitations that cannot be corrected	28.91	30.26
		Plateau		0.78	0.82
		Total		95.543	100

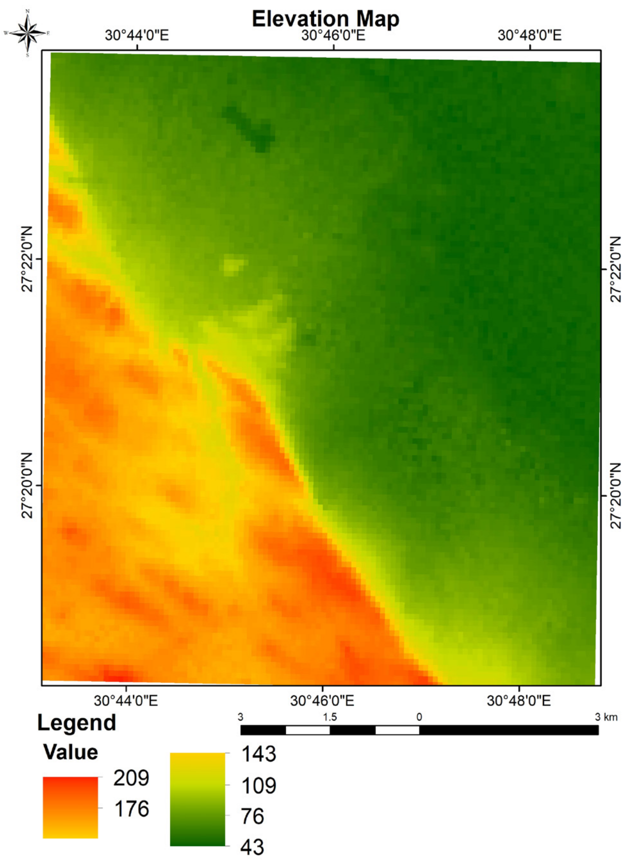

Fig. 4. The elevation map of the studied area

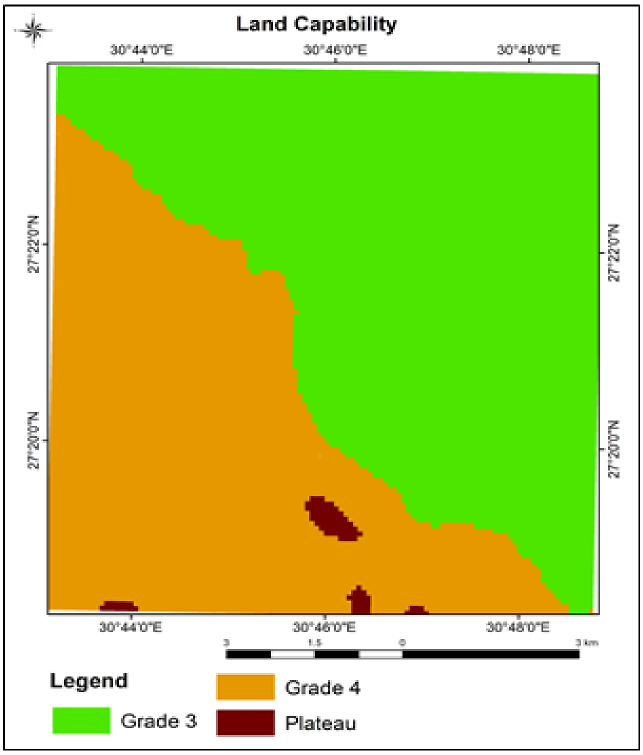

Fig. 5. The land capability map of the studied soils using Storie index

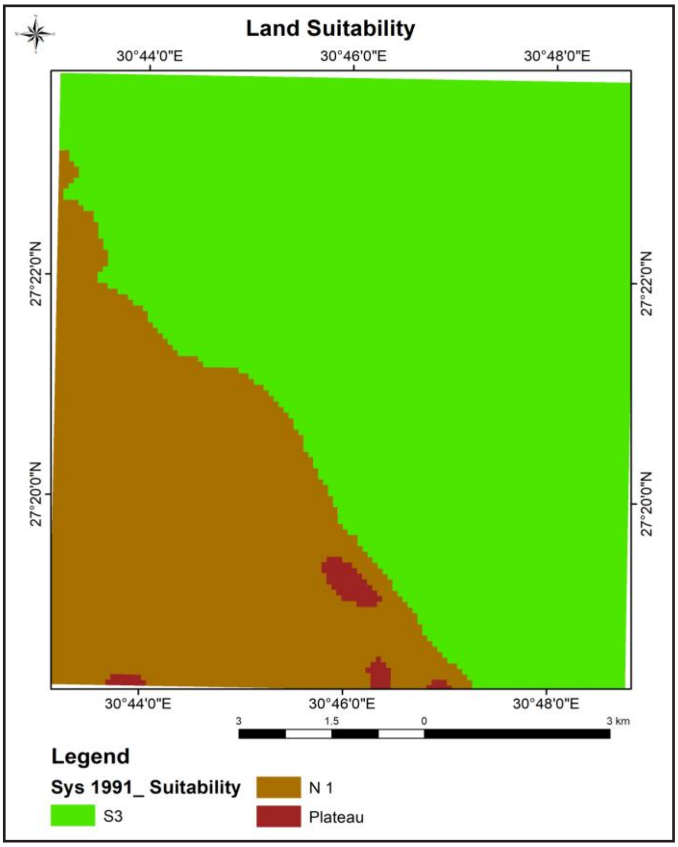

Fig. 6. The land suitability map of the studied soils by Sys and Verheye

The Microcomputer land evaluation information system (MicroLEIS DSS)

General land capability using MicroLEIS DSS (Cervatana model)

Cervatana model to get a specific evaluation or soil factor interpretation prediction for landuse capability was applied. Results representing that land capability evaluation classes of the study area are good (S2)) that occupied an area about 62.8 km^2 of the total study area, moderate (S3) that occupied an area about 3.05 km^2 of the total study area and marginal (N) that occupied an area about 28.91 km^2 of the total study area with limitation factors of soil (i), erosion risks (r) and bioclimatic deficit (b) as presented in Table 9 and Fig. 7.

Agricultural land suitability using MicroLEIS DSS (Almagra model)

Agricultural soil suitability by Almagra model was run to assess the suitability appraisal of different crops for the investigated area based on physio-chemical evaluation of soil characteristics. In this study, 12 crops were selected to be evaluated (Wheat, Maize, Watermelon, Potato, Soybean, Cotton, Sunflower, Sugar beet, Alfalfa, Peach, Citrus, and Olive) using soil criteria as useful depth, stoniness, texture, drainage, carbonate content, salinity, sodium saturation and soil profile development. The result showed that land suitability evaluation classes of the study area are; high suitable (S2), moderate suitable (S3), marginally suitable (S4) and not suitable (S5) with limitation factors of texture (t), drainage (d), carbonate (c), salinity (s), sodium saturation (a) and profile development (g). The most preponderant limiting factors are salinity and sodium saturation which difficult to be improving due to parent material salt enriched such as limestone and high evaporation rate that cause salt accumulation in the soil layers, (Table 9 and Fig. 8a,b and c).

TABLE 9. Land capability and suitability of the studied soil profiles using the MicroLIES (Cervatana and Almagra models)

Profile No.	Capability	Wheat	Maize	Water melon	Potato	Soybean	Cotton	Sunflower	Sugar beet	Alfalfa	Peach	Citrus	Olive
1	Nib	S5s	S5s	S5s	S5s	S5s	S4s	S5s	S4s	S4s	S5s	S5s	S5s
2	S2irb	S3a	S4a	S3sa	S3a	S3a	S3a	S3a	S3a	S3a	S3sa	S3sa	S3sa
3	S3i	S5s	S5sa	S5s	S5s	S5s	S4sa	S5s	S4sa	S4sa	S5s	S5s	S5s
4	Ni	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
5	Ni	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
6	S3ir	S4a	S5a	S4a	S4a	S4a	S4a	S4a	S4a	S4a	S4a	S4a	S4a
7	Ni	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
8	Ni	S5s	S5sa	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s	S5s
9	S2b	S2cag	S3a	S2tag	S2tag	S2cag	S2tg	S2cag	S2cg	S2cag	S2tag	S2tag	S2tca
10	S2rb	S2dag	S3a	S2tdc	S2tdc	S2dsa	S2tdc	S2dsa	S2dg	S2dsa	S2tdc	S2tdc	S2tds

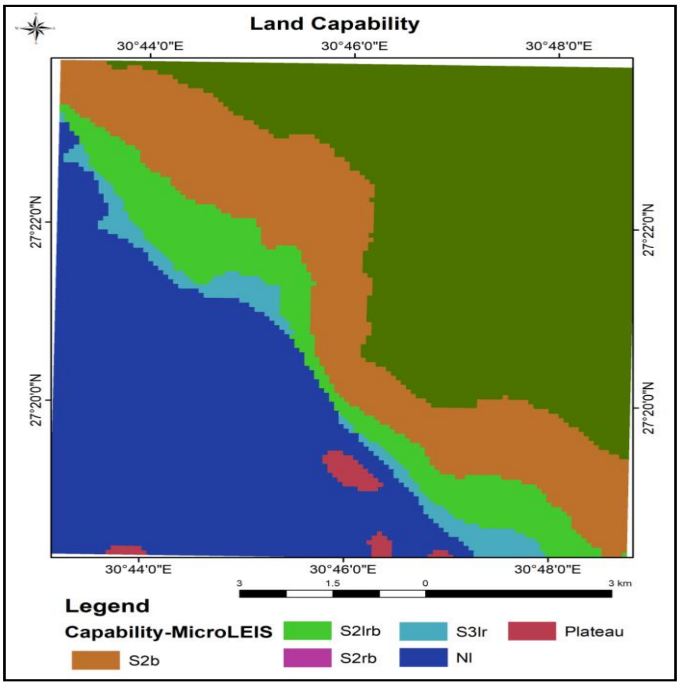

Fig. 7. The land capability map of the studied soils using MicroLEIS (Cervatana model)

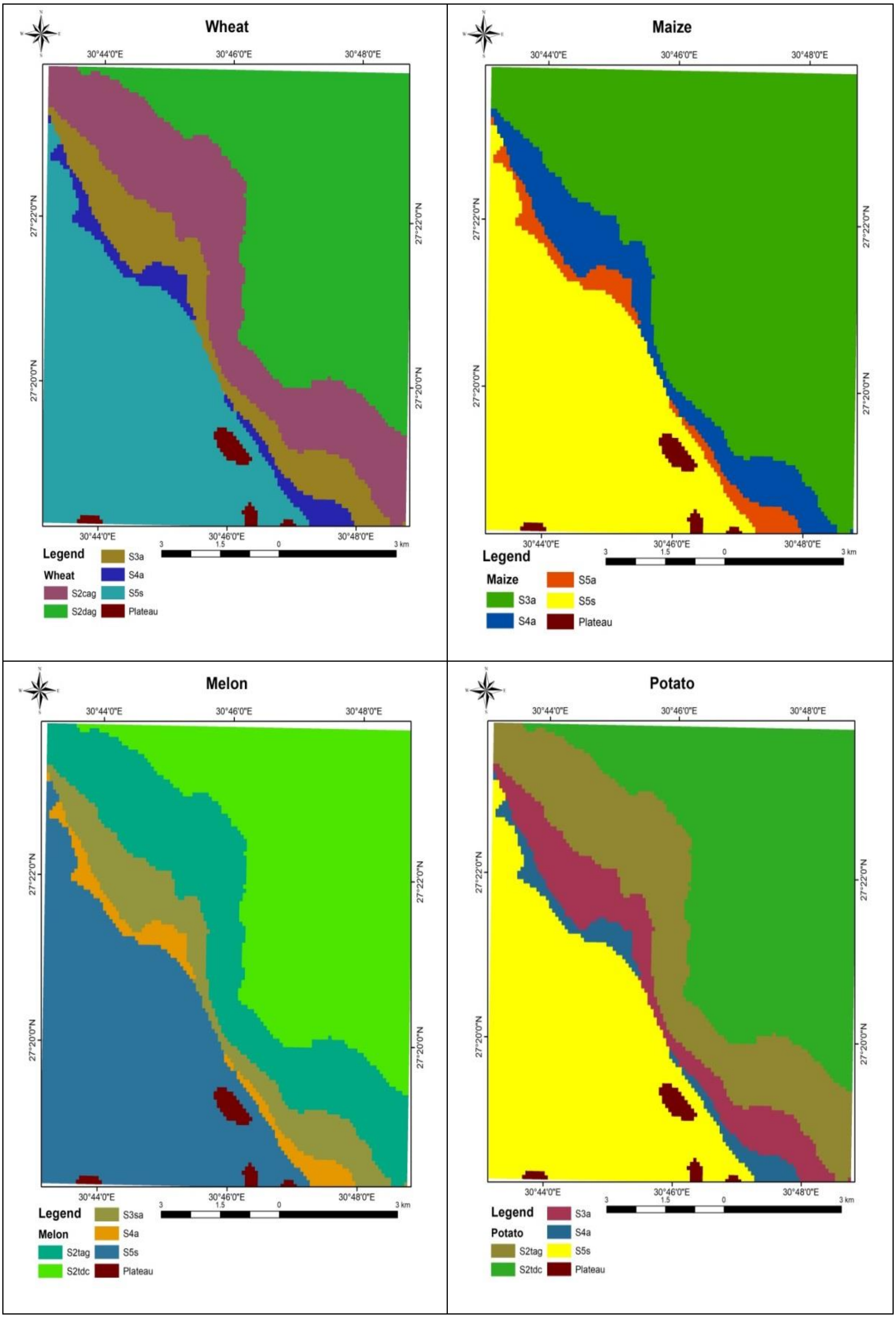

Fig. 8a. The land suitability map of the tested crops using MicroLEIS (Almagra model)

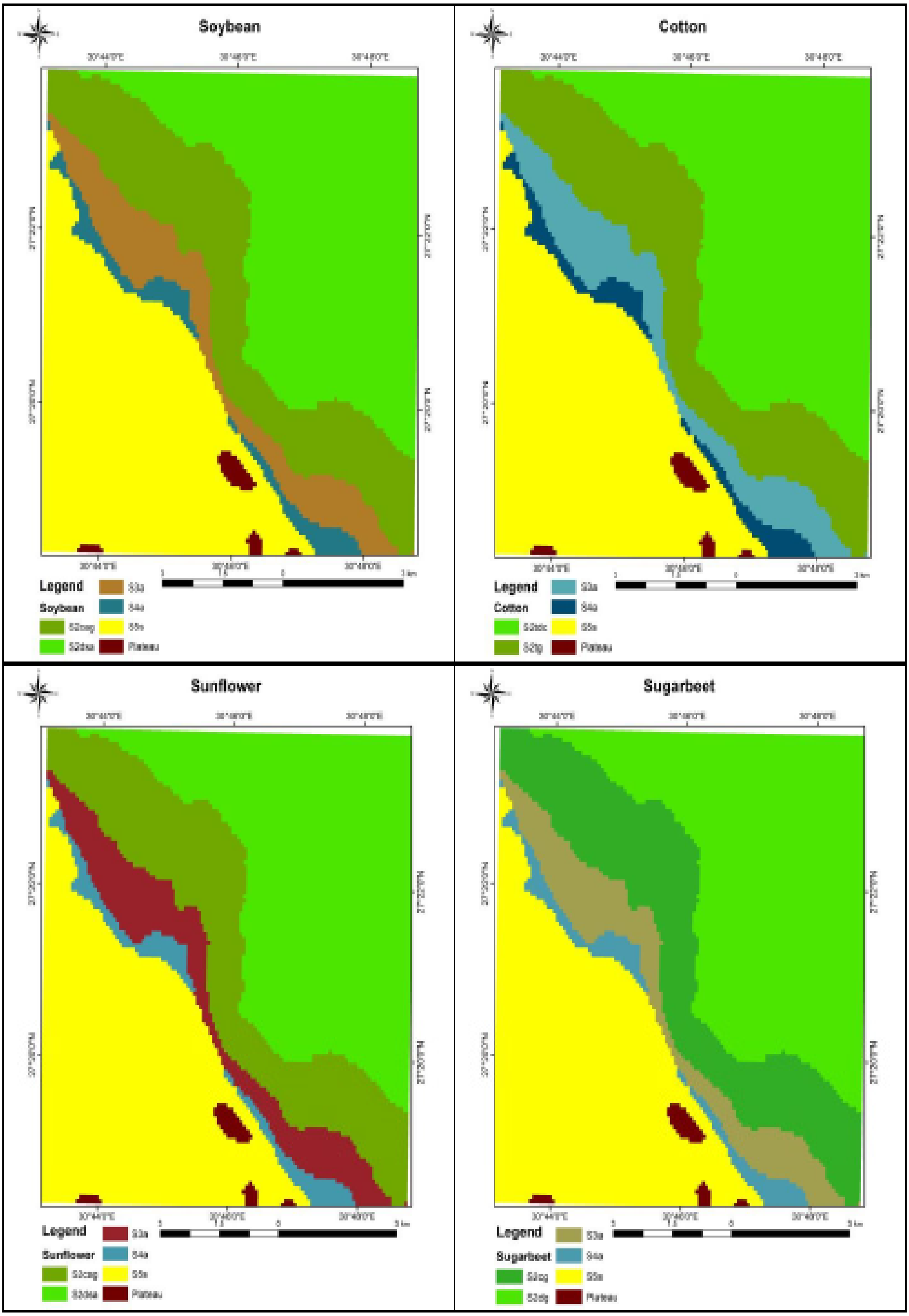

Fig. 8b. The land suitability map of the tested crops using MicroLEIS (Almagra model)

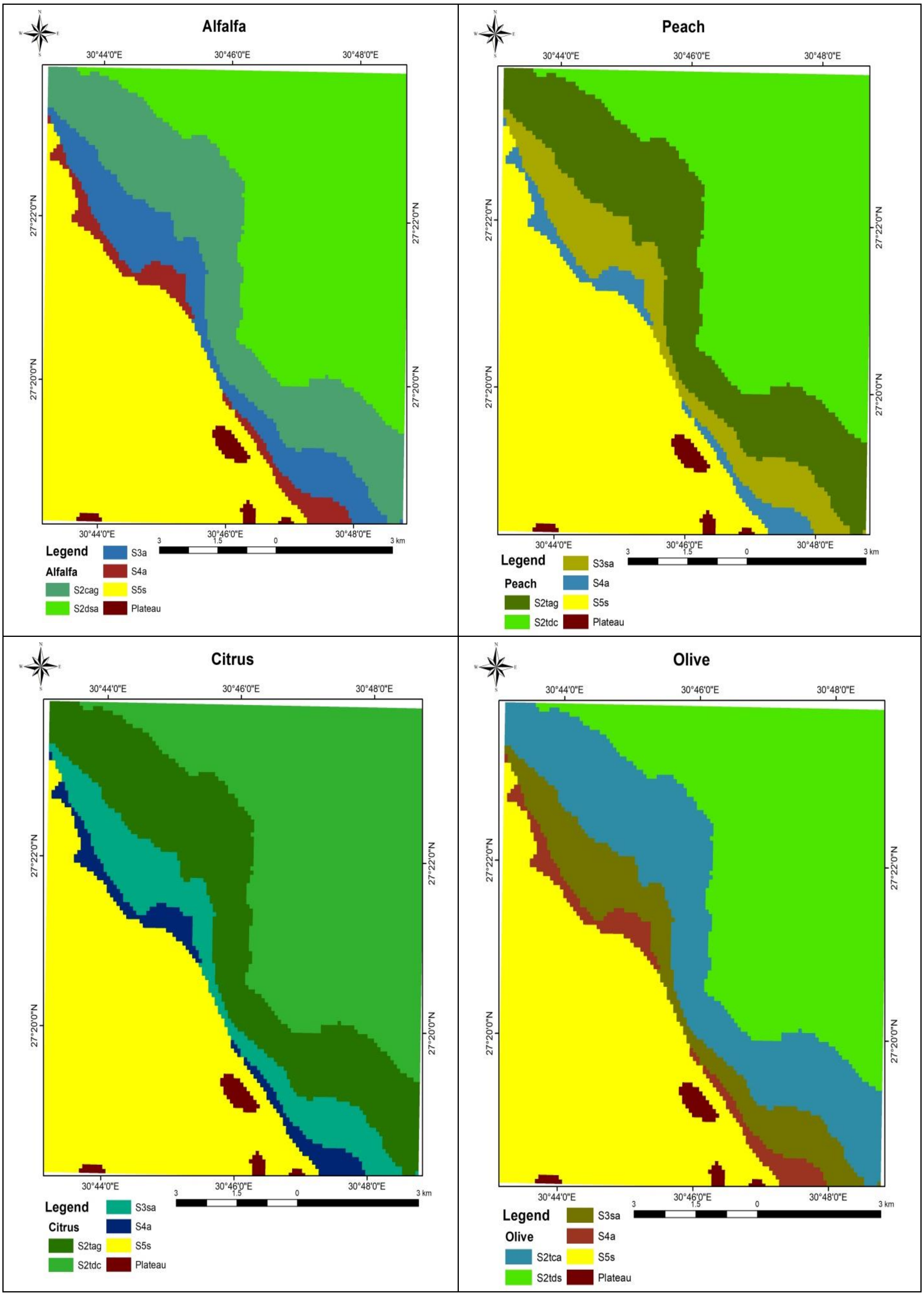

Fig. 8c. The land suitability map of the tested crops using MicroLEIS (Almagra model)

Conclusion

Soil physo-chemical characteristics integration is essential to evaluate land capability and land suitability to achieve agriculture sustainability soil. By applying Storie index for soil capability, the results represented two capability class; fair (grade 3) and poor (grade 4). According to Sys and Verheye system, suitability index for irrigation showed two class (marginal suitable S3 and presently not suitable N1). However, using microcomputer land evaluation information system (MicroLEIS DSS) models (Cervatana and Almagra) for land capability and suitability, resulted indicated that, land capability evaluation classes of the study area were good (S2), moderate (S3), and marginal (N) with limitation factors of soil (i), erosion risks (r) and bioclimatic deficit (b). The land suitability evaluation classes of the study area were; high suitable (S2), moderate suitable (S3), marginally suitable (S4) and not suitable (S5) with limitation factors of texture (t), drainage (d), carbonate (c), salinity (s), sodium saturation (a) and profile development (g). The most preponderant limiting factors were salinity and sodium saturation for the tested crops (Wheat, Maize, Watermelon, Potato, Soybean, Cotton, Sunflower, Sugar beet, Alfalfa, Peach, Citrus, and Olive). The investigated area realized slightly to very severe limitations, that neutralize agricultural practices use. Therefore, this area required special management practice for soil conservation.

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تقييم الموارد الأرضية لمواكبة تنمية التربة المستدامة في منطقة القوصية، أسيوط، مصر

محمد الادهم فضل[١] و ياسر عبد العال سيد[٢]

[١]شعبة التدريب العلمي والدراسات المستمرة - الهيئة القومية للاستشعار من البعد وعلوم الفضاء - القاهرة - مصر
[٢]قسم علوم الأراضي والمياه - كلية الزراعة - جامعة الأزهر- أسيوط - مصر

من الضروري زيادة المساحة المزروعة في مصر لتلبية احتياجات السكان المتزايدة. ومع ذلك، فإن التقييم الدقيق للأراضي يشكل مصدر اهتمام كبير لتحقيق الإنتاج الزراعي المستدام. وهكذا، هدفت الدراسة الحالية إلى تقييم قدرة الأرض وملاءمة المحاصيل في مدينة القوصية، محافظة أسيوط، مصر باستخدام تقنيات الاستشعار من البعد (RS) ونظم المعلومات الجغرافية (GIS) حيث تم حفر عشر قطاعات تمثل التربة المدروسة ذات المرجعية الجغرافية والتي تمثل الوحدات الجيومرفولوجية في منطقة الدراسة حتى عمق ١٥٠ سم أو حتى الطبقات الصماء. وتنتمي تربة منطقة الدراسة إلى فئتين من القدرة الانتاجية للتربة وفقًا لمؤشر Storie وهى وسطية (الدرجة ٣) وفقيرة (الدرجة ٤). وفئتان ملائمتان وفقًا لنظام Sys وVerheye وهى هامشية المناسبة(S3) وغير مناسبة حاليًا (N1) كما أظهر نموذج Cervatana أن فئات القدرة الانتاجية للتربة في منطقة الدراسة هي جيدة (S2) ، معتدلة (S3) وهامشية (N) مع عوامل تحد من الانتاجية وهى عوامل التربة (i) ، مخاطر التآكل (r) والعجز المناخي الحيوي (b) ويوضح نموذج Almagra لتقييم ملاءمة الأرض لزراعة المحاصيل المختلفة أن منطقة الدراسة تنتمي إلى فئات ملائمة هي عالية الملائمة (S2) ، مناسبة الى متوسطة الملائمة(S3) ، ومناسبة هامشيًا للملائمة (S4) وغير ملائمة (S5) وكانت العوامل المحددة للإنتاجية في منطقة الدراسة والأكثر وضوحًا مع المحاصيل المختارة هي ملوحة التربة وتشبع التربة بالصوديوم.