Land Suitability Assessment for Crop Production in Banger Elsoker Region of Egypt

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ABSTRACT: Land evaluation is the process of assessing the possible uses of land for different purposes. Land suitability analysis is a method of land evaluation, which measures the degree of appropriateness of land for a certain use. The present study is a quantitative evaluation of land to determine land suitability in Banger Elsokar district for different crop cultivations based on some pedological variables, as soil salinity, soil depth, soil reaction (pH), calcium carbonate and soil texture that are mandatory input factors for crop cultivation. The studied area was classified on the basis of their capability to the classes C2, C3 and C4. The quantitative approach given by FAO (1976) has been used also to classify the area on the basis of their capability to good capability (5700.2 hectares), poor capability (500.62 hectares) and very poor capability (443.77 hectares). Classifying the land on the basis of their suitability , the ranked classes were S1, S2, S3, S4, NS1 and NS2. This study proposes an integrated methodology for analyzing and mapping of land suitability using the Remote Sensing and GIS techniques. The result indicated that the demarcated areas as highly suitable for crops cultivation were 3785.52 hectares for sunflower, 6635.25 hectares for wheat, 6336.19 hectares for tomato, 6200.82 hectares for watermelon, 2581.24 hectares for olive, 3785.52 hectares for grape and 2196.04 hectares for apple.

Keywords: Land Evaluation, Land suitability, Land Capability, GIS, Overlap

INTRODUCTION

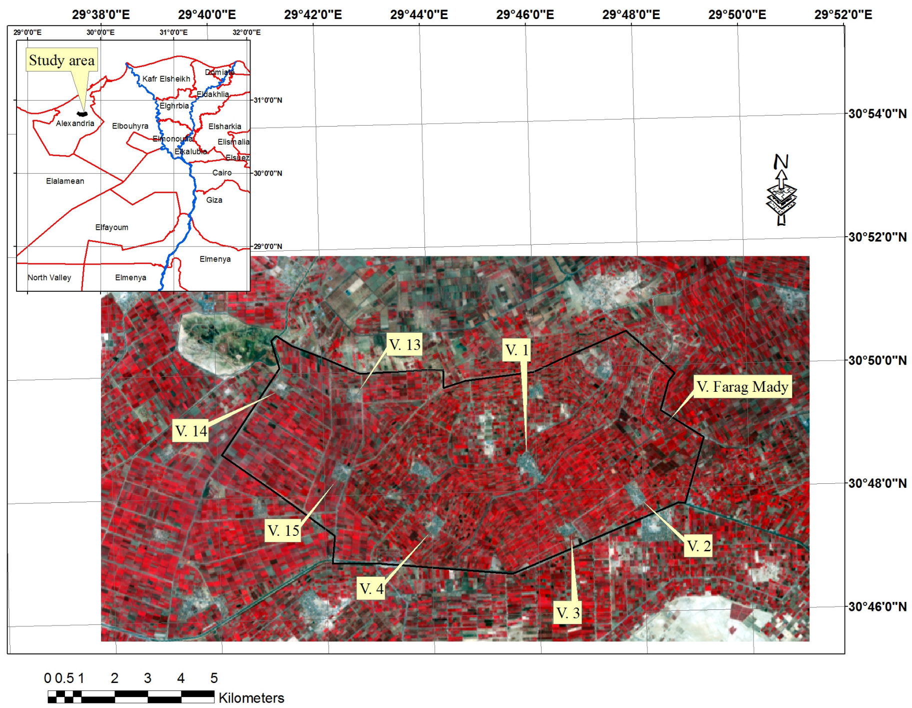
The population of the planet is growing dramatically. However, the potential of the land for crop production to satisfy the demand of the ever increasing population is declining as the result of sever soil degradation. Empirical studies indicate that severe degradation of soils' productive capacity has occurred on over 10% of the Earth's vegetated land as a result of soil erosion, excessive tillage, and overgrazing etc. (Lal, 1994). Considering the rapid growth of the world's population, which is in its turn a limiting factor to the arable lands around the world, the need for effective and efficient application of the croplands have been felt more than ever (Teklu, 2005; Behzad *et al*., 2009). Hence, much attention is given to selection of crop which suits an area the best. The concept of sustainable agriculture involves producing quality crops in an environmentally friendly, socially acceptable and economically feasible way (Addeo *et al*., 2001). Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use (FAO, 1976). The FAO defined that, the suitability is a function of crop requirements and land characteristics and it is a measure of how will the qualities of a land unit match the requirements of a particular form of land use (FAO, 1976). In Egypt, Banger Elsokar region has considerable potential for agriculture activities. Generally, the soil of this region suffers from physical, chemical and fertility implications so land evaluation effort should be done.

The aim of this study was to depict the spatial variability of some soil properties and to evaluate the land capability and suitability for selecting the proper cropping pattern for the different crops commonly grown in the area to overcome the major pedological constraints.

MATERIALS AND METHODS

Study Area

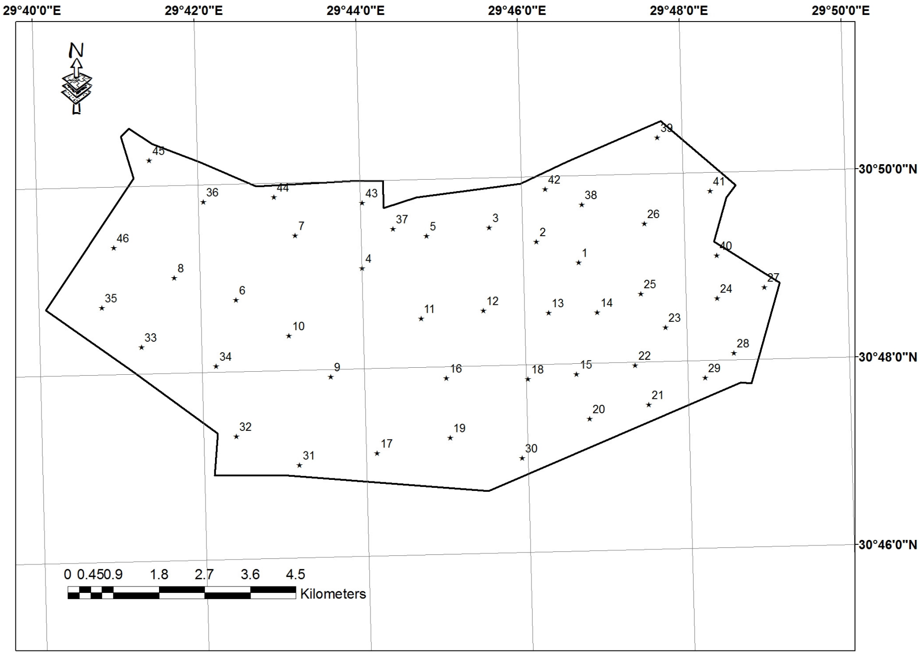
The study area is located between latitudes 30^{o} 46 ′ 30 ″ and 30^{o} 50 ′ 45 ″ N and longitudes 29^{0} 40 ′ 15 ″ and 29^{o} 49 ′ 15 ″ E covering area of 7074.34 hectare (16906.86 acres) (map1). The study area includes Bangar El-Sokar Districts, Behira Governorate, Egypt.



Map (1). General location of the study area boundary on the rectified ETM^{+} Landsat image (2015).

Field and Laboratory work

To characterize the land units for the study area, forty six auger samples were dug using Grid system to cover the area. The location of their augers is shown in map (2).



Map (2). Soil auger samples distribution at study area districts

The soil samples was taken from surface and subsurface layer as wel were air dried and greatly reused with a wooden pestle, sieved though 2 mm sieves and then subjected to laboratory analysis. The soil chemical and physical analysis were carried out according to the methods described in (Page *et al.*, 1982). The tested soil properties were presented in Table(1). Water samples were analyzed in order to characterize the water quality.

Satellite Image

A window of Land sat 8 ETM+ (Enhanced Thematic Mapper plus) image acquired in may. 2015 was selected to represent the study area as shown in map (1).

*Image Registration

Image registration is the first step to be carried out before proceeding to any further image processing. This step will assign coordinate systems to the image and linked it to its location on the ground. The ETM+ image captured in May. 2015 was geometrically rectified to the digitized topographic maps using image-to-map procedure in ENVI 4.8 software (ENVI, 2008).

*Resolution Merge

This dialog enables you to integrate imagery of different spatial resolutions (pixel size). Since higher resolution imagery is generally single band (ETM^+ Panchromatic 15 m data), while multispectral imagery generally has the lower resolutions (ETM^+ 30 m). These techniques are often used to produce high resolution, multispectral imagery. This improves the interpretability of the data by having high resolution information which is also in color. Resolution Merge offers three techniques: Multiplicative, Principal Components, and Brovey Transform (ERDAS, 2008).

***Generation of DEM**

The digitized contour lines and spot heights were utilized by Contour Gridder extension to generate the Digital Elevation Model (DEM) within ArcGIS 10.3 environment. The Digital Elevation Model (DEM) is analyzed to generate the degree of slope classes and Aspect.

Descriptive statistical parameters

Minimum, maximum, mean, standard deviation and coefficient of variance were calculated using SPSS software Ver. 12 (2003).

Building up Digital Georeference Database

Data input process is the operation of entering the spatial and non-spatial data into GIS using Arc-GIS 10.3 software. Each soil observation was geo-referenced using the Global Position Systems (GPS) and digitized. The different soil attributes were coded, and new fields were added to the profile database file in Arc/View software. Surface interpolate grid were done for soil salinity, Soil depth, $CaCO_3$ % using module Arc Scripts in ArcGIS 10.3 (ESRI, 2014).

Land evaluation

Land capability and suitability evaluation have been done using ALES-Arid as shown in Fig (1) (Abd El-Kawy *et al.*, 2010).

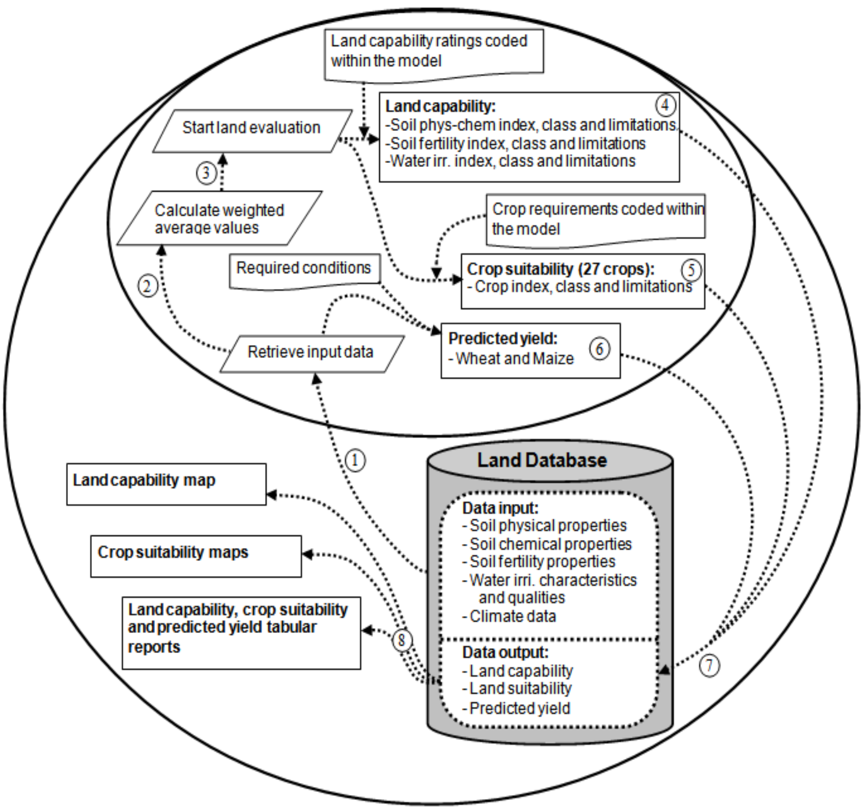


Fig. (1). The structure of ALES arid-GIS. The inner circle shows the model steps (the land evaluation processes) and the outer circle represents the GIS framework (ArcMap platforom).

RESULTS AND DISCUSSION

Characterization of the studied soil profiles attributes

Table (1 and 2) indicates the statistical parameters of the soil profiles for the different soil horizons. The soil depth ranged from 40 cm to 120 cm with median value about 70 cm. The coefficient of variation of the soil depth (0.30) shows that the soil depth was homogeneous in study area. Soil salinity ranged from 0.68 to 14.32 and 0.24 to 5.82 dS/m at surface and sub-surface layer with median 1.46 and 1.48. On the other hand, the coefficient of variation was less in homogeneity for surface soil salinity and sub-surface layer (1.04, 0.56). The homogeneity properties were observed with sand%, clay%, $CaCO_3$ % (0.12, 0.23, 0.16), for surface layer and (0.20, 0.37, 0.17) for sub surface layer, respectively. Other less homogeneity was observed for silt (0.94 and 0.79) for surface and sub-surface respectively.

Table (1). Statistical parameters of soil depth

Properties	Min	Max.	Range	Median	S.E.	S.D.	Var	CV
Soil depth,cm	40	120	80	70	3.495	23.702	561.8	0.30

Table (2). Characteristics and the main statistical parameters of soil profiles samples of the study area

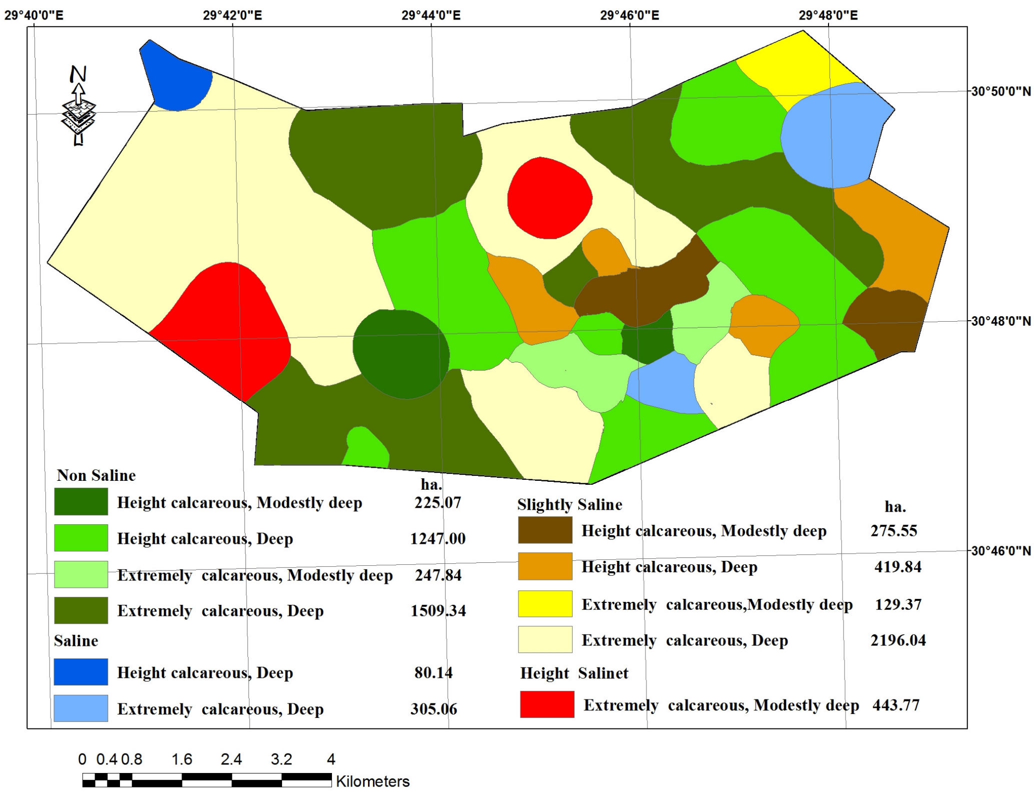
	min	Max	Range	Median	S.E	S.D.	Var.	C.V
Surface layer (0 - 30)								
pH	7.23	8.53	1.30	8.00	0.05	0.34	0.12	0.04
EC, dS/m	0.68	14.32	13.64	1.46	0.36	2.47	6.08	1.04
Ca, meq/l	1.00	20.20	19.20	4.00	0.70	4.76	22.64	0.92
Mg, meq/l	0.70	22.00	21.30	7.00	0.76	5.13	26.31	0.74
Na, meq/l	2.30	125.00	122.70	8.10	2.78	18.83	354.63	1.50
K, meq/l	0.43	6.90	6.47	1.10	0.26	1.75	3.06	0.81
HCO_3, meq/l	1.00	3.00	2.00	2.00	0.08	0.57	0.32	0.34
Cl, meq/l	1.50	34.10	32.60	3.85	0.90	6.08	36.94	1.07
SO_4, meq/l	2.00	110.30	108.30	14.63	2.70	18.30	334.80	0.94
SAR	1.24	44.33	43.09	4.12	0.94	6.39	40.86	1.15
$CaCO_3$, %	20.50	44.00	23.50	30.00	0.73	4.97	24.74	0.16
Clay, %	14.10	36.60	22.50	22.20	0.78	5.30	28.12	0.23
Silt, %	0.50	32.38	31.88	5.50	0.92	6.24	38.94	0.94
Sand, %	45.52	84.80	39.28	71.90	1.25	8.50	72.24	0.12
Sub Surface layer (30 - 60)								
pH	7.56	8.60	1.04	8.05	0.04	0.28	0.08	0.04
EC, dS / m	0.24	5.82	5.58	1.48	0.15	1.00	0.99	0.56
Ca, meq/l	1.20	13.00	11.80	6.00	0.42	2.85	8.11	0.45
Mg, meq/l	0.60	9.00	8.40	2.70	0.26	1.74	3.04	0.65
Na, meq/l	1.65	16.90	15.25	3.39	0.58	3.93	15.45	0.71
K, meq/l	0.28	6.10	5.82	0.78	0.23	1.53	2.35	0.89
HCO_3,meq/l	1.00	3.00	2.00	1.10	0.07	0.45	0.20	0.35
Cl, meq/l	1.00	10.10	9.10	2.00	0.42	2.82	7.94	0.80
SO_4, meq/l	5.40	21.80	16.40	10.65	0.64	4.31	18.56	0.38
SAR	0.64	8.02	7.38	1.60	0.33	2.22	4.91	0.76
$CaCO_3$, %	20.50	45.50	25.00	34.60	0.86	5.82	33.90	0.17
Clay, %	10.00	55.60	45.60	24.60	1.58	10.74	115.42	0.37
Silt, %	0.50	28.30	27.80	5.50	1.01	6.84	46.79	0.79
Sand, %	38.80	80.40	41.60	61.65	1.84	12.46	155.21	0.20

Soil mapping units of the study area were extracted from the overlay of the main soil properties in the Arc-GIS 10.3 such as soil depth, soil salinity and total calcium carbonate Eleven soil units were identified in the studied area as shown in Map (3) and Table (3) included the area in hectars percentage of each soil unit.

Soil units of the studied area

The soils were classified into main four soil units and eleven sub-units based on the diagnostic horizons and variability , soil salinity, calcium carbonate content , soil texture, and profile depth as:

1- Non Saline soil unit was 45.62% and Salin soil unit was 5.44 % of the studied area.
2- Extremely calcareous, Deep soil sub-unit ewas (2196.04 ha) 31.02% and Highly calcareous, Deep soil sub-unit was (80.14 ha) 1.13% as shown in Table (3) and Map (3).

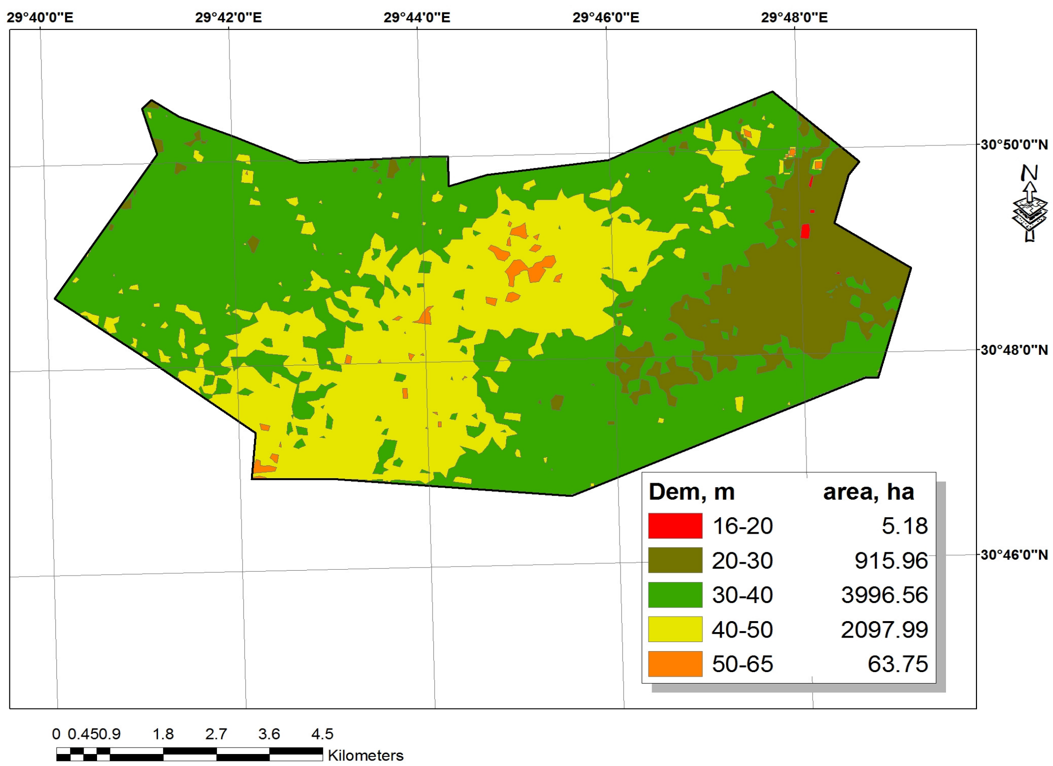


Map (3). Soil mapping units distribution in the study area

Table (3). Soil units of the studied area

Code	Description	Area (hectares)	%
	Non Saline		
1101	Highly calcareous, Modestly deep	225.071	3.18
1102	Highly calcareous, Deep	1247.00	17.62
2101	Extremely calcareous, Deep	1509.34	21.32
2102	Extremely calcareous, Modestly deep	247.84	3.50
Total		3229.251	45.62
	Slightly Saline		
1201	Highly calcareous, Modestly deep	275.55	3.89
1202	Highly calcareous, Deep	419.84	5.93
2201	Extremely calcareous, Modestly deep	129.37	1.83
2202	Extremely calcareous, Deep	2196.04	31.02
Total		3020.8	42.67
	Saline		
1302	Highly calcareous, Deep	80.14	1.13
2302	Extremely calcareous, Deep	305.06	4.31
Total		690.26	5.44
	Highly Saline		
2401	Extremely calcareous, Modestly deep	443.77	6.27

The analysis of Digital Elevation Model (DEM) indicated that the elevations ranged between > 16 m A.S.L. to < 65 m A.S.L. The main elevation from 30 m A.S.L.to 50 m A.S.L. covers an area about of 6094.55 hactares as shown in Map (4).



Map (4). Digital Elevation Model (DEM) of study area.

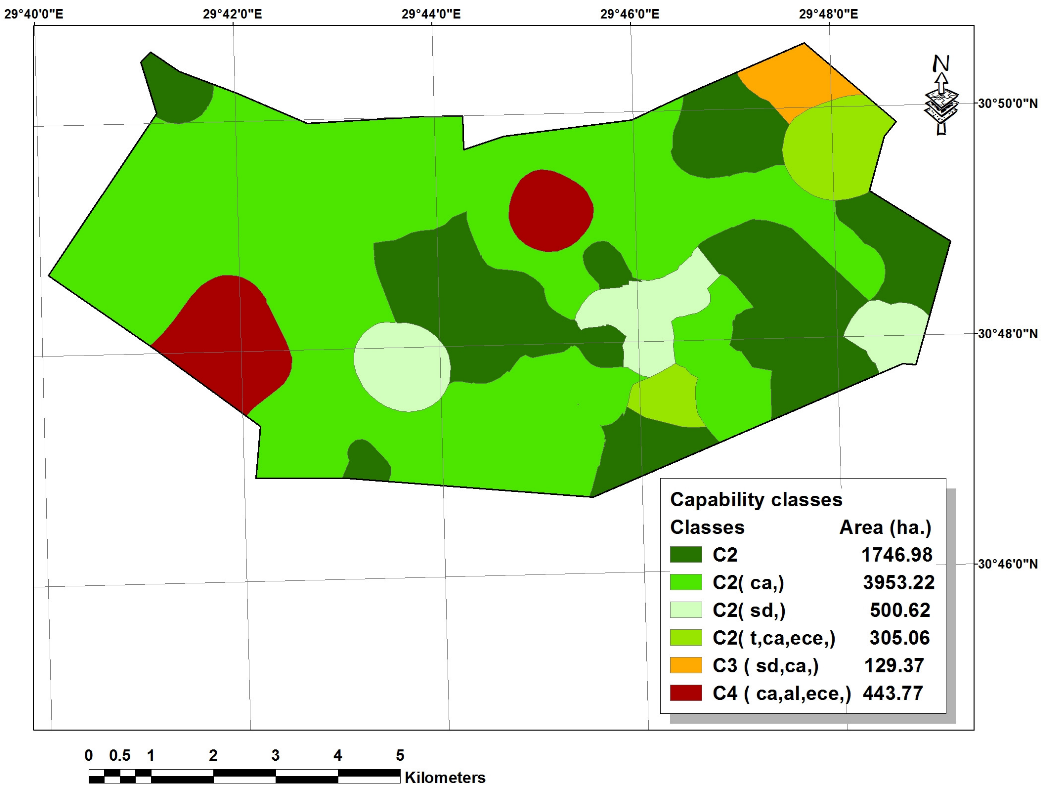
Land capability classes

The ALES Model (Applied Land Evaluation System) provides prediction for general land use capability for a broad series of possible uses. Indicating the limiting factors on the covering area. Map (5) shows the distribution of each land use capability class in the studied area. According to the model prediction, most of the study area was classified as (C2 , C2 (ca)), which indicated good capability with high calcium carbonate percentage as limiting factor which covered about 5700.2 hectares, followed by (C2 (sd)), which indicated very good capability with soil depth class as limiting factor which covered about 500.62 hectares. On the other hand, 443.77 hectares belongs to (C4 (ca, al, ece)), which indicated poor capability with high calcium carbonate percentage, alkalinity and soil salinity as limiting factor.

Land suitability classes for specific land uses

The ALES model was used to predict soil suitability for some common crops cultivated in the study area including: wheat, maize, alfalfa, fababean, onion, tomato, banana, citrus, fig and watermelon. Data of soil suitability class and sub class are presented in the maps (6, 7, 8, 9, 10, 11, 12 and 13) and Table (4) which indicates the distribution of suggested cultivated crops for each soil units in the studied area.

The suitability maps have been proposed acceding to five suitability categories namely; S1, S2, S3, S4 and Ns. From the obtained maps for the different crops, the obtained results can be summarized on follows:



Map (5). Land capability classes for the studied area.

a. field crops:

1-Suitability classes of sunflower were S1(3785.52 ha) (53.38%) and S3(443.77 ha)(6.27%).

2-Suitability classes of wheat were S1(1247.0) (17.62%), S1(t) (5388.25) (76.12%),and S2(ece,t) (433.70 ha) (6.13%).

b. vegetable:

1- Suitability classes of tomato were S1(6330.19 ha) (89.42%), S2 ece (305.06 ha) (4.31%) and S4 (ece, Ca), (443.77 ha) (6.27%).

2- Suitability classes of Watermelon were S1 (6200.82 ha) (87.59%), S2 (129.37 ha) (1.83%), S2(ece)(305.06 ha) (4.31%) and S4(ece)(443.77 ha) (6.27%).

c. Fruit trees:

1- Suitability classes of Banana were S3(t, Ca) (2276.18 ha) (32.15%), S3 (t, Ca, sd) (1509.34 ha) (21.32%), S4 (ece, t, Ca) (305.06 ha) (4.31%), Ns2 (sd) (2544.67 ha) (35.95%) and Ns2(sd, Ca) (443.77 ha) (6.27%).

2- Olive suitability classes were S1 (2581.24 ha) (36.46%), S1 (sd) (1509.34 ha) (21.32%), S4 (ece, sd) (443.77 ha) (6.27%) and Ns2 (sd) (2544.67 ha) (35.95%).

3- Grape Suitability classes were S1 (3785.52 ha) (53.48%), S2 (sd) (1914.68 ha) (27.05%), S2 (ece) (305.06 ha) (4.33%) and Ns2 (1073.76 ha) (15.17%).

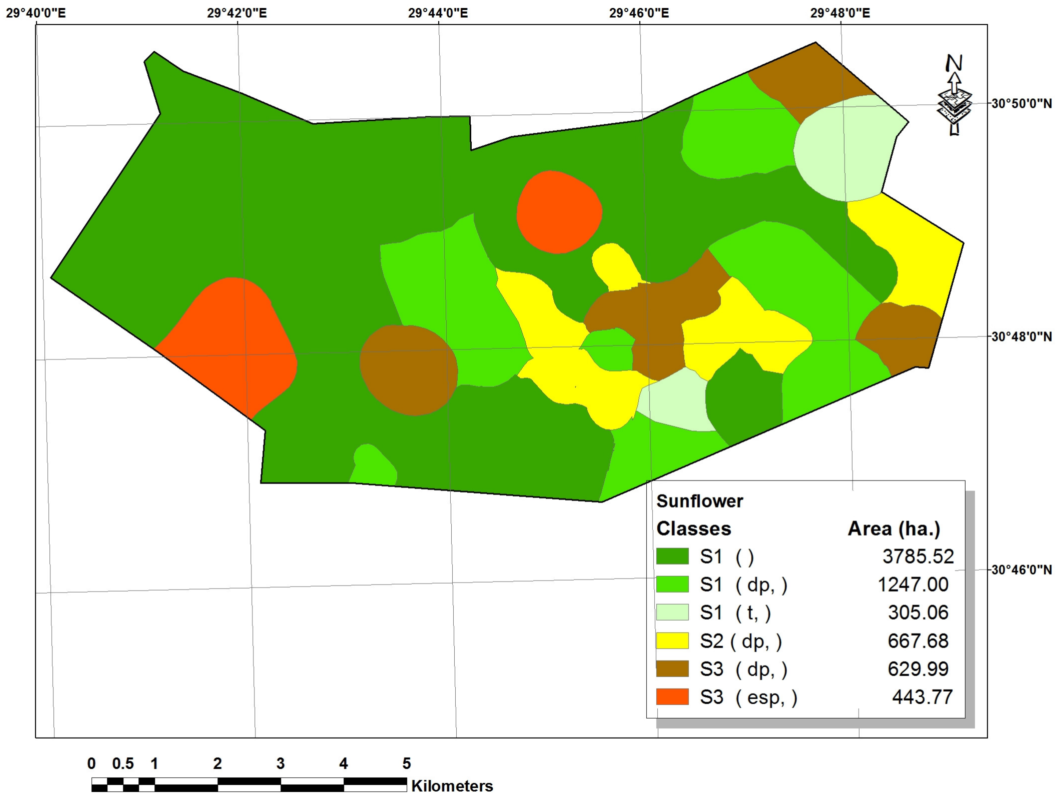
4- Suitability classes of Apple were S1 (2196.04 ha) (31.02%), S2 (80.14 ha) (1.13%), S2 (ece) (305.06 ha) (4.31%) and Ns2 (sd) (2988.44 ha) (42.22%).

Table (4). Land suitability classes for specific uses

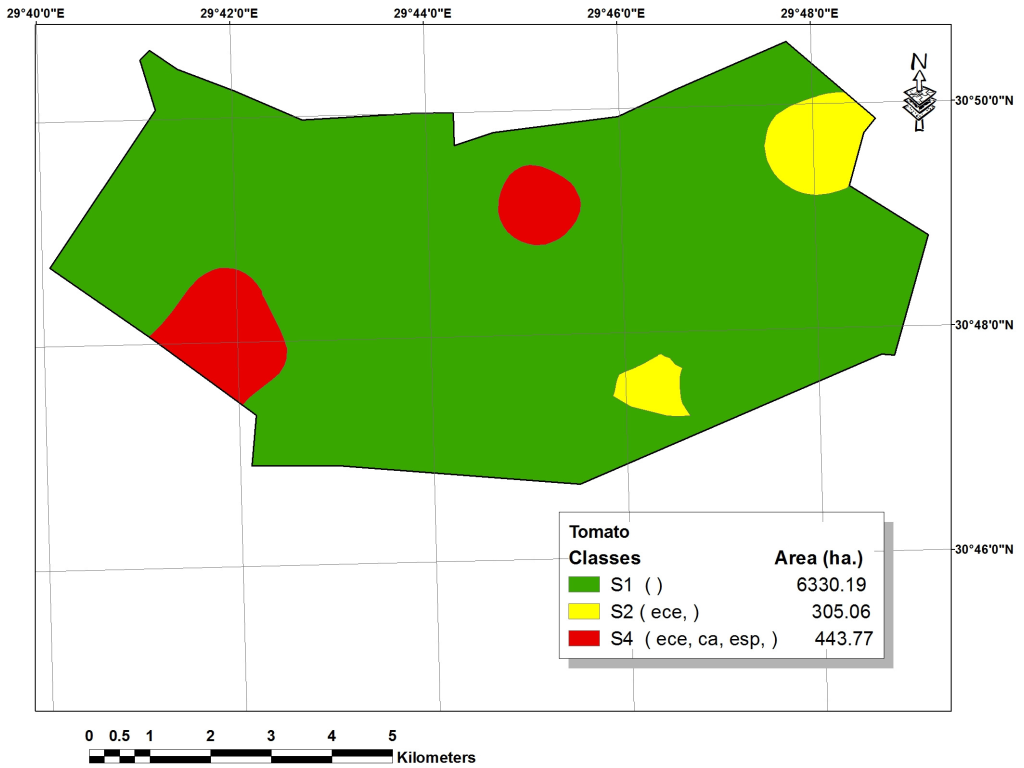
units code	1101	1102	2101	2102	1201	1202	2201	2202	1302	2302	2401
soil _Class	C2(sd)	C2	C2(ca)	C2(ca)	C2(sd)	C2	C3(sd,ca)	C2(ca)	C2	C2(t,ca,ece)	C4(ca,al,ece)
Wheat	S1(t)	S1	S1(t)	S1(t)	S(t)	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S2(ece, t)
Barley	S1(t)	S1	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S2(t)	S2(t)
Faba_bean	S2	S1	S2	S1	S2	S2	S2	S1	S2(ece)	S3(ece,t)	S4(ece)
Sugarbeat	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2(t)	S3
Sunflower	S3(sd)	S1(sd)	S2(sd)	S1	S3(sd)	S2(sd)	S3(sd)	S1	S1	S1(t)	S2(sd)
Rice	S1(t)	S1	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	S1(t)	NS2(t)	S3(ece,t)
Maize	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2(ece,t)	S4(ece)
Soyabean	S3(sd)	S2(sd)	S2(sd)	S2	S3(sd)	S2(sd)	S3(sd)	S1	S2(ece)	S3(ece,t)	S4(ece,sd)
Peanut	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S4(ece,ca)	S4(ece,ca)
Cotton	S3(sd)	S1(sd)	S2(sd)	S1	S3(sd)	S2(sd)	S3(sd)	S1	S1	S2(t)	S3(sd)
Sugarcane	S3(sd,t)	S2(sd)	S2(sd,t)	S2(t)	S3(sd,t)	S2(sd,t)	S3(sd,t)	S1(t)	S1(t)	S2(t)	S3(ece,sd,t)
Citrus	NS2(sd,ca)	NS2(sd,ca)	NS2(sd, ca)	NS2(ca)	NS2(sd,ca)	NS2(sd,ca)	NS2(sd,ca)	NS2(ca)	NS2(ca)	NS2(ca)	NS2(sd,ca)
Banana	NS2(sd)	NS2(sd)	NS2(sd)	S3(sd,t,ca)	NS2(sd)	NS2(sd)	NS2(sd)	S3(t,ca)	S3(t,ca)	S4(ece,t,ca)	NS2(sd)
Grape	NS2(sd)	S2(sd)	S2(sd)	S1	NS2(sd)	S2(sd)	NS2(sd)	S1	S1	S2(ece)	S4(ece, sd)
Olive	NS2(sd)	NS2(sd)	NS2(sd)	S1(sd)	NS2(sd)	NS2(sd)	NS2(sd)	S1	S1	S1	NS2(sd)
Apple	NS2(sd)	NS2(sd)	NS2(sd)	S2(sd)	NS2(sd)	NS2(sd)	NS2(sd)	S1	S2	S3(ece,t)	NS2(sd)
Pear	NS2(sd)	NS2(sd)	NS2(sd)	S2(sd,t)	NS2(sd)	NS2(sd)	NS2(sd)	S2(t)	S2(t)	S3(ece,t)	NS2(sd)
Fig	NS2(sd)	NS2(sd)	NS2(sd)	S1(sd)	NS2(sd)	NS2(sd)	NS2(sd)	S1	S1	S1	NS2(sd)
Date_palm	NS2(sd)	NS2(sd)	NS2(sd)	S1(sd)	NS2(sd)	NS2(sd)	NS2(sd)	S1	S1	S1	NS2(sd)
Onion	S1	S1	S2	S1	S1	S2	S2	S1	S2(ece)	S3(ece,t)	S3(ece)
Cabbage	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2(ece,t)	S3(ece)
Pea	S2	S1	S2	S1	S2	S2	S2	S1	S2(ece)	S3(ece,t)	S3(ece)
Potato	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ca)	S3(ece,ca)	S4(ece,ca)
Tomato	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2(ece)	S3(ece)
Pepper	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2(ece)	S4(ece)
Watermelon	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2(ece)	S4(ece)
Alfalfa	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2(ece)
Sorghum	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2(t)	S4(ece)

(Classes): C1= Excellent, **C2**=Good, **C3**=Fair, **C4**=poor, **C5**=Very Poor, **C6**=Non-agriculture. **S1**=Highly suitable, **S2**=Moderately suitable, **S3**=Marginally suitable, **S4**=Conditionally suitable. **NS1**=Potentially suitable, **NS2**= Actually unsuitable.

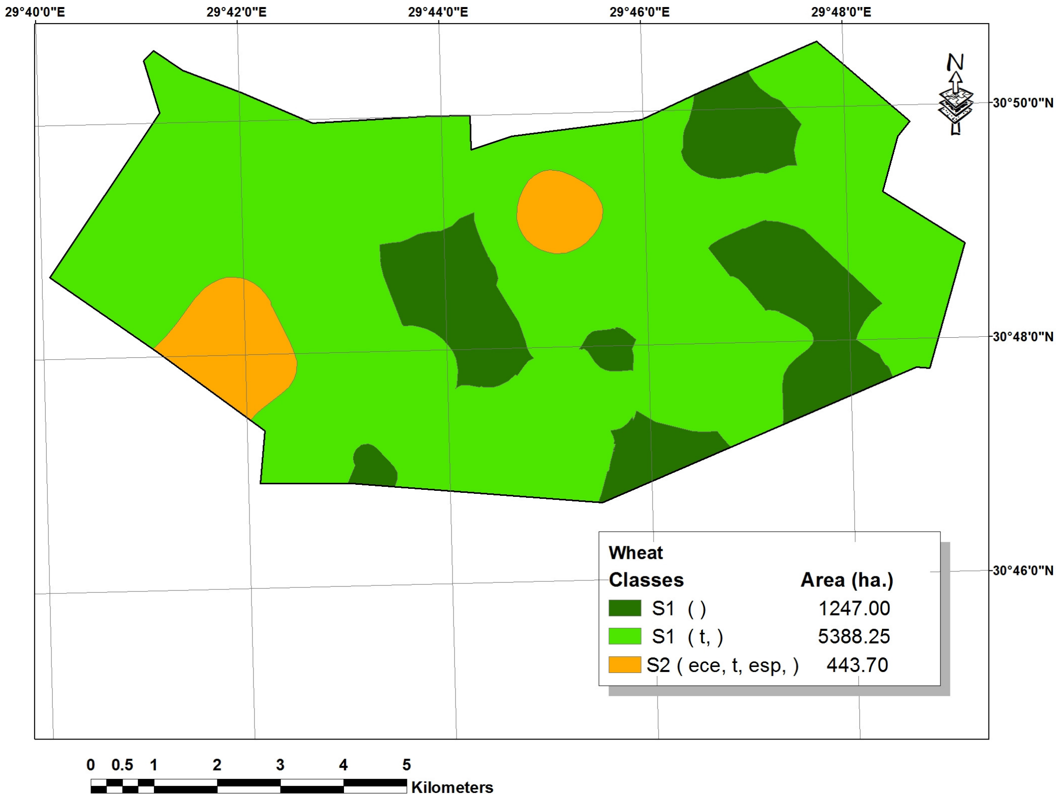
(Soil Sub Classes): t = Clay, **sd**= soil depth, **ca**= $CaCo_3$, **ece** = Soil salinity.



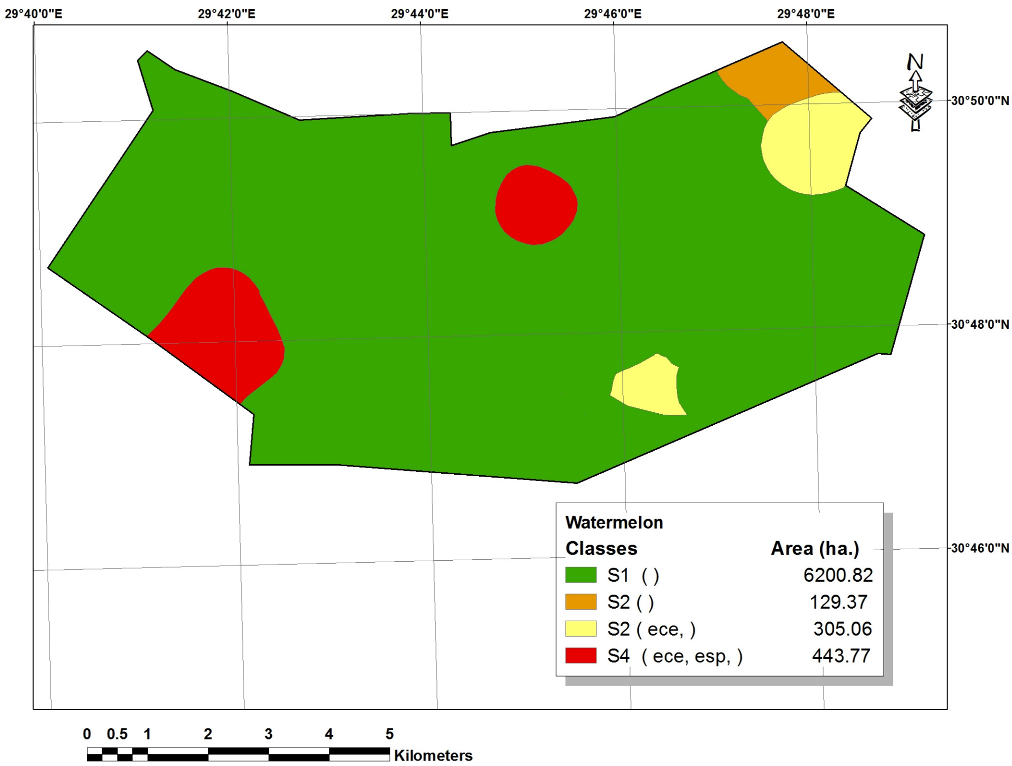
Map(6). land suitability for sunflower.



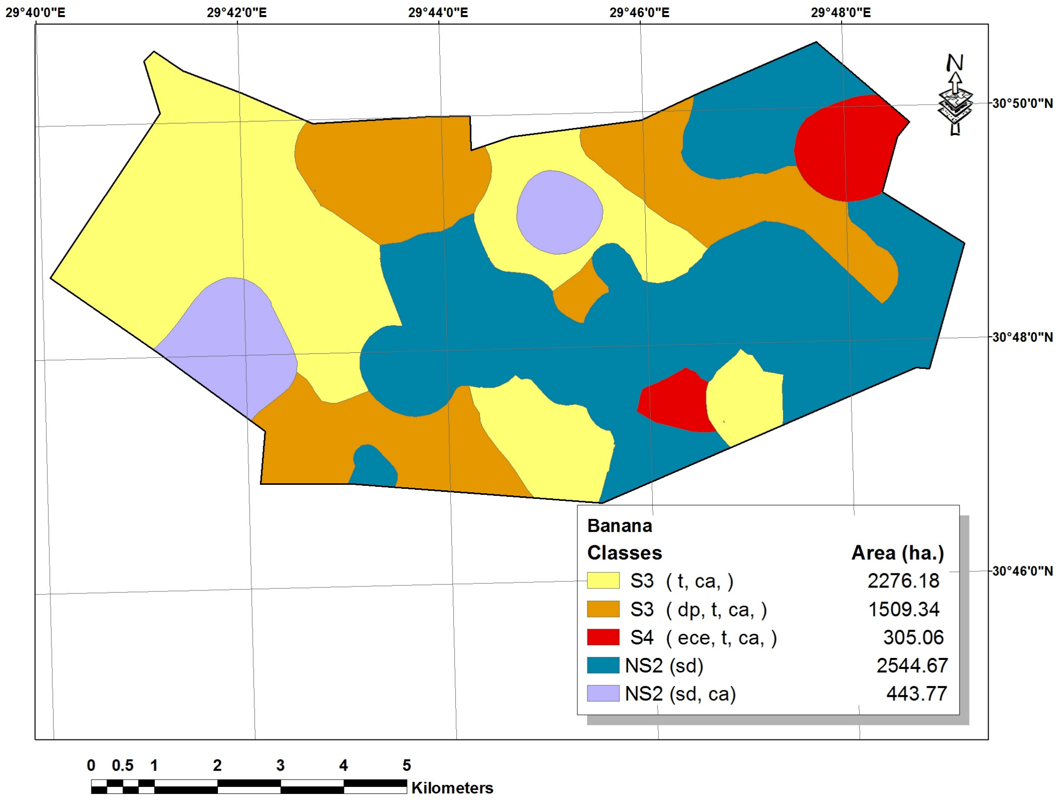
Map(7). land suitability for Tomato.



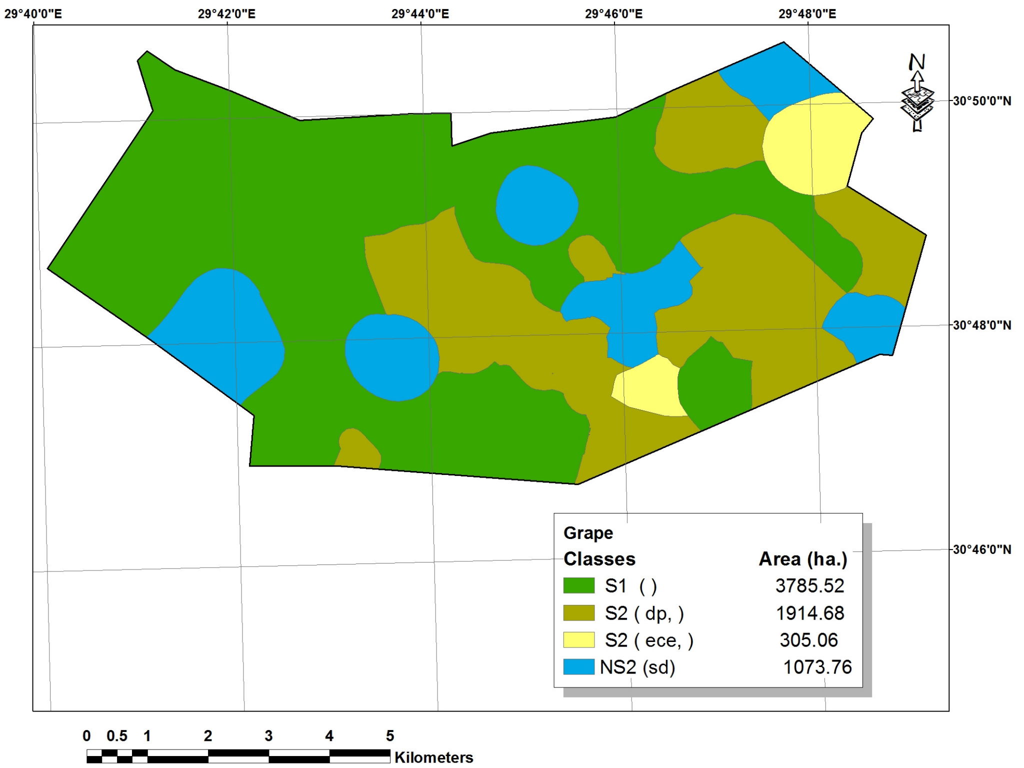
Map(8). land suitability for Wheat



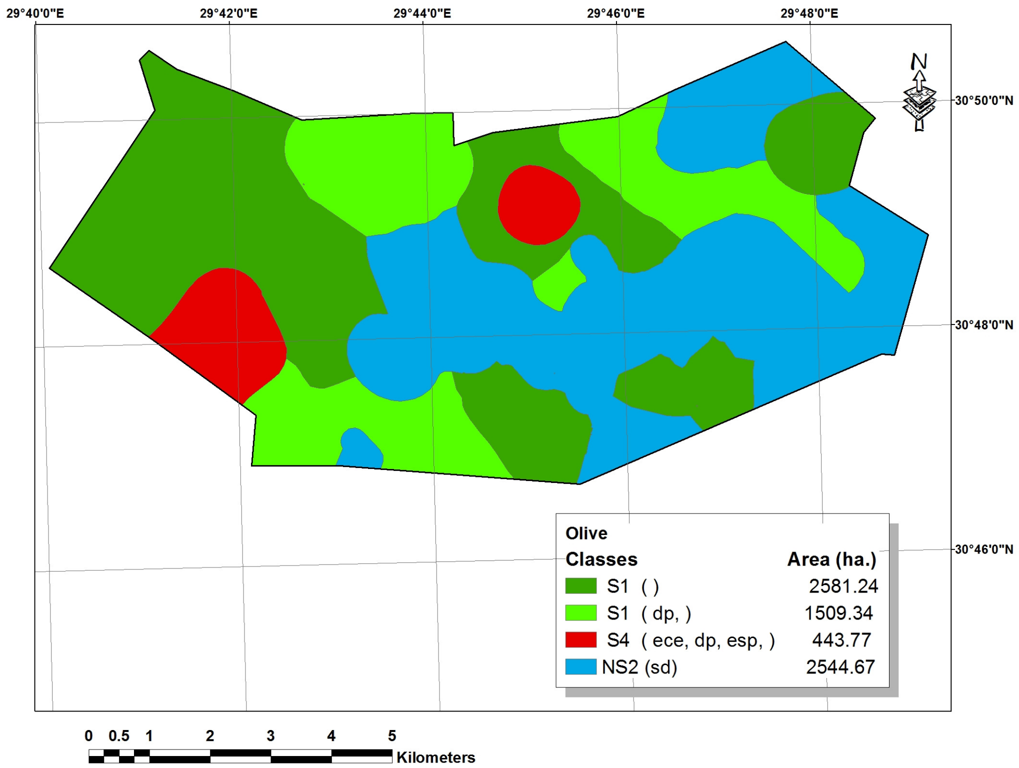
Map(9). land suitability for Watermelon



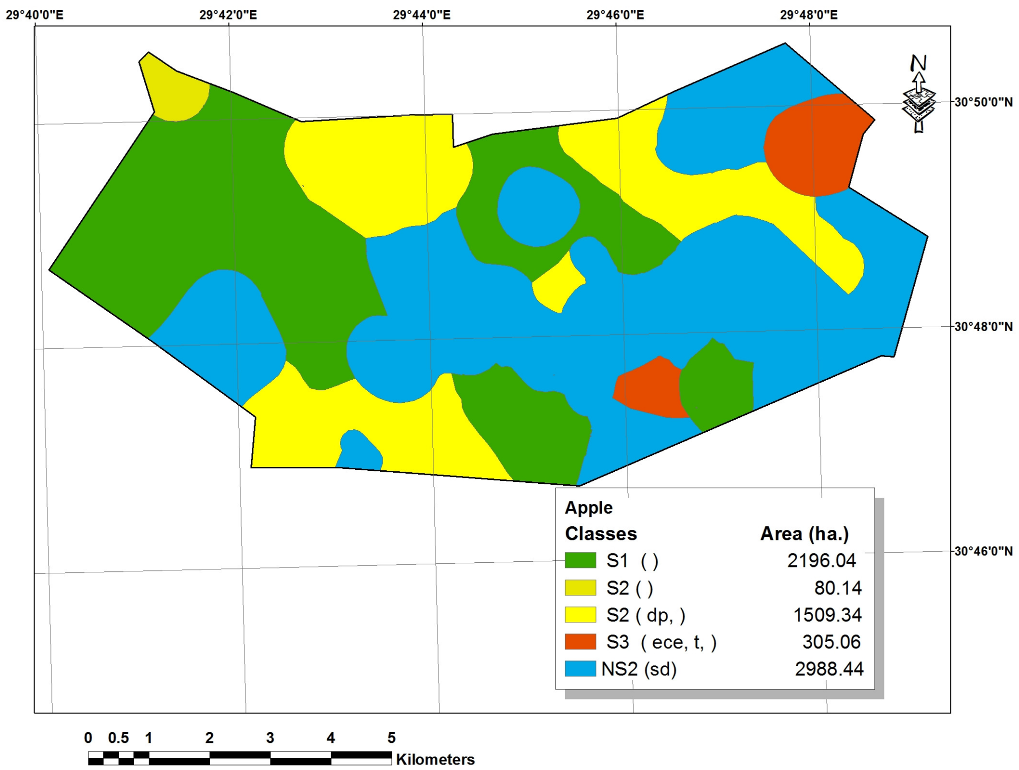
Map (10). land suitability for Banana



Map(11). land suitability for Grape



Map (12). Land suitability for Olive



Map(13). land suitability for Apple

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الملخص العربي

تقييم ملاءمة الأراضي لإنتاج المحاصيل في منطقة بنجر السكر بمصر

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**مختبر بحوث الأراضي الملحية والقلوية – معهد الأراضي والمياه والبيئة بمركز البحوث الزراعية

أجريت هذه الدراسة الحقلية في منطقة بنجر السكر الواقعة في جنوب غرب محافظة الاسكندرية، وعلى بعد ٧٠ كم تقريبا. تهدف هذه الدراسة الى انشاء قاعدة بيانات جغرافية رقمية مسجلة لأراضي المنطقة وحفظ هذه البيانات في الحاسب الالي ثم اجراء تقييم خواص وصفات الارض وذلك للمساعدة في اختيار انسب انواع المحاصيل التي يمكن زراعتها في منطقة الدراسة. وتقييم الأرض هي عملية تقييم الاستخدامات الممكنة من الأراضي لأغراض مختلفة. تحليل ملاءمة الأرض هو وسيلة لتقييم الأراضي، والذي يحدد درجة ملاءمة الأرض لاستخدام معين. هذه الدراسة هي تقييم نوعي للأرض لتحديد مدى صلاحية الأراضي لزراعة المحاصيل المختلفة التي تزرع عادة من قبل المزارعيين في منطقة بنجر السكر. استنادا إلى بعض المتغيرات والعوامل المتعلقة بالتربة مثل ملوحة التربة، وعمق التربة (sd)، درجة تفاعل التربة (pH)، وكربونات الكالسيوم (Ca) وقوام التربة (t) وهي عوامل مساهمة ضرورية لزراعة المحاصيل. وقد صنفت منطقة الدراسة على أساس قدرتها للانتاج الزراعي الى (C4, C3, C2). تم إعداد تقييم الأراضي وفقا لمبادئ تقييم الأرضي حسب منظمة الأغذية والزراعة (١٩٧٦). أيضا لتصنيف المنطقة على أساس قدرتها على أنتاج المحاصيل فكانت قدرة أنتاجها جيدة (٥٧٠٠,٢ هكتار)، ومتوسطة القدرة الأنتاجية (٥٠٠,٦٢ هكتار)، وقدرة انتاجية فقيرة (٤٤٣,٧٧ هكتار).وتم تصنيف الأراضي على أساس مدى ملاءمتها للمحاصيل الزراعية، فكانت تصنيفها على سبيل المثال (S1، S2، S3، S4، NS1، NS2) في هذه الدراسة، تم استخدام نظم المعلومات الجغرافية كأداة لتوقيع تقييم مدى ملاءمة الأرض للزراعة وملائمتها لأنواع مختلف من المحاصيل . وأشارت النتيجة أن المناطق المناسبة جدا لزراعة المحاصيل كانت ٣٧٨٥,٥٢ هكتار لعباد الشمس، ٦٦٣٥,٢٥ هكتار للقمح، ٦٣٣٦,١٩ هكتار للطماطم، ٦٢٠٠,٨٢ هكتارللبطيخ، ٢٥٨١,٢٤ هكتار للزيتون، ٣٧٨٥,٥٢ هكتار للعنب و ٢١٩٦,٠٤هكتار للتفاح.