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Land Suitability Evaluation for Different Crops in Soils of Eastern Sohag, Egypt

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Abstract: *This study aimed to evaluate land suitability for cultivating different crops in some soils of the Eastern part of Sohag Governorate. Six soil profiles were drilled, and soil samples were collected from each horizon. Soil profiles were described morphologically in situ. Soil samples were prepared and analyzed for their physical, chemical, and fertility parameters using the standard methods. Climatic data, as well as soil morphological, physical, chemical, and fertility data of the studied soils were used to evaluate and classify land capability using different indices. These data were used also to evaluate and classify land suitability for cultivating different crops using the parametric method and ALES model. The results of this study prevailed that, the soils of the studied site ranged between poor to fair capability (using Storie index) and from very poor to fair capability (using Sys and Verheye index). Regarding soil suitability evaluation using the parametric method, the studied area ranged between marginally suitable (S3) and moderately suitable (S2) for cultivating Wheat, Maize, Alfalfa, Tomato, Olives, and Mango. Using the ALSE model, soils ranged from non-suitable (N1) to moderately suitable (S2) for cultivating the evaluated crops. The limitations of these soils are soil texture, ECe, and SOM. Land capability and suitability maps were generated using the interpolation tool of QGIS software. These data and maps can be used for better planning for new lands reclamation and for enhancing land efficiency for crop productivity.*

Keywords— Storie Index, Parametric method, ALSE, land capability, land suitability, Sohag soils, mapping, QGIS.

1. INTRODUCTION

The current situation in Egypt is full of challenges, especially in the agricultural sector, due to the increase in the population and the decrease of cultivated areas. The government focuses on establishing agricultural development projects through horizontal expansion and reclamation of new lands, which represent the eastern and western desert belt of the various Egyptian governorates' borders. The reclamation and cultivation of these types of lands are very difficult but necessary to solve the problem of food scarcity and achieve self-sufficiency (Abd El-Kawy *et al.*, 2010). When commencing the reclamation of a new area, adequate studies should be conducted in that area. Therefore, soil science is found to be very important for completing these tasks related to studying the different properties of soils and giving the necessary recommendations to achieve the maximum benefit from the lands. Moreover, the evaluation of lands in terms of their production capacity and their suitability to grow different crops is very important for decision-makers to achieve better utilizing of these lands and also cultivate crops that will achieve the highest productivity. There are many methods used to evaluate and classify land capability, such as the FAO (1976), Storie index (1954), Sys and Verheye (1975), etc. These methods aim to evaluate the land capability and classifying them into several categories according to quality. These methods depend on the use of different soil data such as physical, chemical, and fertility properties in calculating land capability. Soil suitability for cultivating different crops can be assessed using different methods that depend on the use of soil parameters and climate data as well as crops-requirements data. The Sys *et al.* (1993) parametric method is commonly used for its comprehensiveness and ease of application. The Agricultural Land Suitability Evaluation (ALES) model (Ismail *et al.*, 2001) has proven to be very efficient, easy, and fast to use. Integration between GIS, methods of assessing land capability, and also suitability is important for better utilization of land (Panigrahy *et al.*, 2006). The production of land capability and suitability maps can benefit farmers and decision-makers in using the land to make optimal use to achieve high agricultural productivity.

Based on what was previously listed, this study aims to (i) evaluate land capability in the eastern part of Sohag Governorate using different evaluation methods, (ii) assess and classify the suitability of lands for cultivating different crops, and (iii) produce land capability and suitability maps using GIS tools.

2. MATERIALS AND METHODS

Study area description

The study site is a part of Wadi Qena in the Eastern Desert. This area lies between the 26°42'12.11", 26°42'26.20" latitudes (N) and 32°45'33.01", 32°53'8.50" longitudes (E) with an area of ≈45.2 km^2. The area under investigation located between the Nile Valley in the West and the Red Sea mountains in the East. The location map of the studied area and soil profiles' locations is shown in figure (1). The geology of Wadi Qena was reported by (El-Shamy 1988). Wadi Qena is covered with Quaternary deposits which are consisting of gravels, sands, and cemented by fine clay materials. Wadi Qena catchment is a typical arid basin, which is characterized by an extremely arid climate. The annual rainfall ranges between 2.75 and 50 mm, while heavy showers are recorded occasionally during winter causing flash floods. The minimum temperature is ranging between 5ºC and 14ºC and the maximum is ranging between 28ºC and 42ºC. The relative humidity (RH) ranges between 30% and 56%. The maximum monthly evapotranspiration is 23.5 mm during June, while the minimum value is 3.1 mm during December (Awad 2008). Prevailing winds are dominantly from the northwest to the southeast with an average maximum speed of 10 knots/h. The natural vegetation is sparse and distributed randomly over the area. *Moringa, Wild Caper,* and *Salvador-prisca* are the common natural vegetation in the area. Furthermore, agricultural activities are very limited in the area (El-Zawahry *et al.* 2004).

Field-work

Six soil profiles were drilled and soil samples were collected carefully from each profile horizons. The geo-coordinates of each soil profile were defined by using GPS "Garmin–eTrix" under the WGS84 coordinate system. A detailed morphological description for all soil profiles was noted *in situ* based on FAO (2006).

Soil analysis

Soil samples were air-dried, grounded, and passed through 2 mm sieve. Soil material (<2 mm) was used for the determination of soil physical and chemical properties as follows: particle size distribution by international pipette method, (Jackson, 1969). Soil reaction (pH) and electrical conductivity (EC) were determined in 1:1 soil-water suspension, calcium carbonate was estimated volumetrically using Colins's calcimeter (Jackson, 1973). Organic matter contents were determined by Walkley and Black method (1934). Cation Exchange Capacity (CEC) was determined by sodium acetate (pH≈8.5) and exchangeable cations by ammonium acetate (pH≈7.0) methods (Black 1982). Exchangeable Sodium Percentage (ESP) was calculated as a ratio of exchangeable Na^+ to CEC. Available Nitrogen was determined using the alkaline potassium permanganate method (Subbiah and Asija 1956). Available Phosphorus was extracted with 0.5*M* $NaHCO_3$ (pH≈8.5) following the procedures outlined by Whatanable and Olsen (1965). Available Potassium was determined by the ammonium acetate (pH≈7.0) method. DTPA extractable micronutrients *viz* iron, manganese, zinc, and copper were measured by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Soil bulk density and soil-water parameters were calculated using SPAW software (Saxton and Rawls 2006).

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The used data of each soil profile was transformed into a weighted mean. Calculation of the mean weighted value for each soil property (V) of the profile calculated by multiplying the summation of (vi) for each horizon by horizon thickness (ti) divided by the profile depth (T) according to equation (1).

$$V = \sum_{i=1}^{n} \frac{(v1 \times ti)}{T} \qquad (1)$$

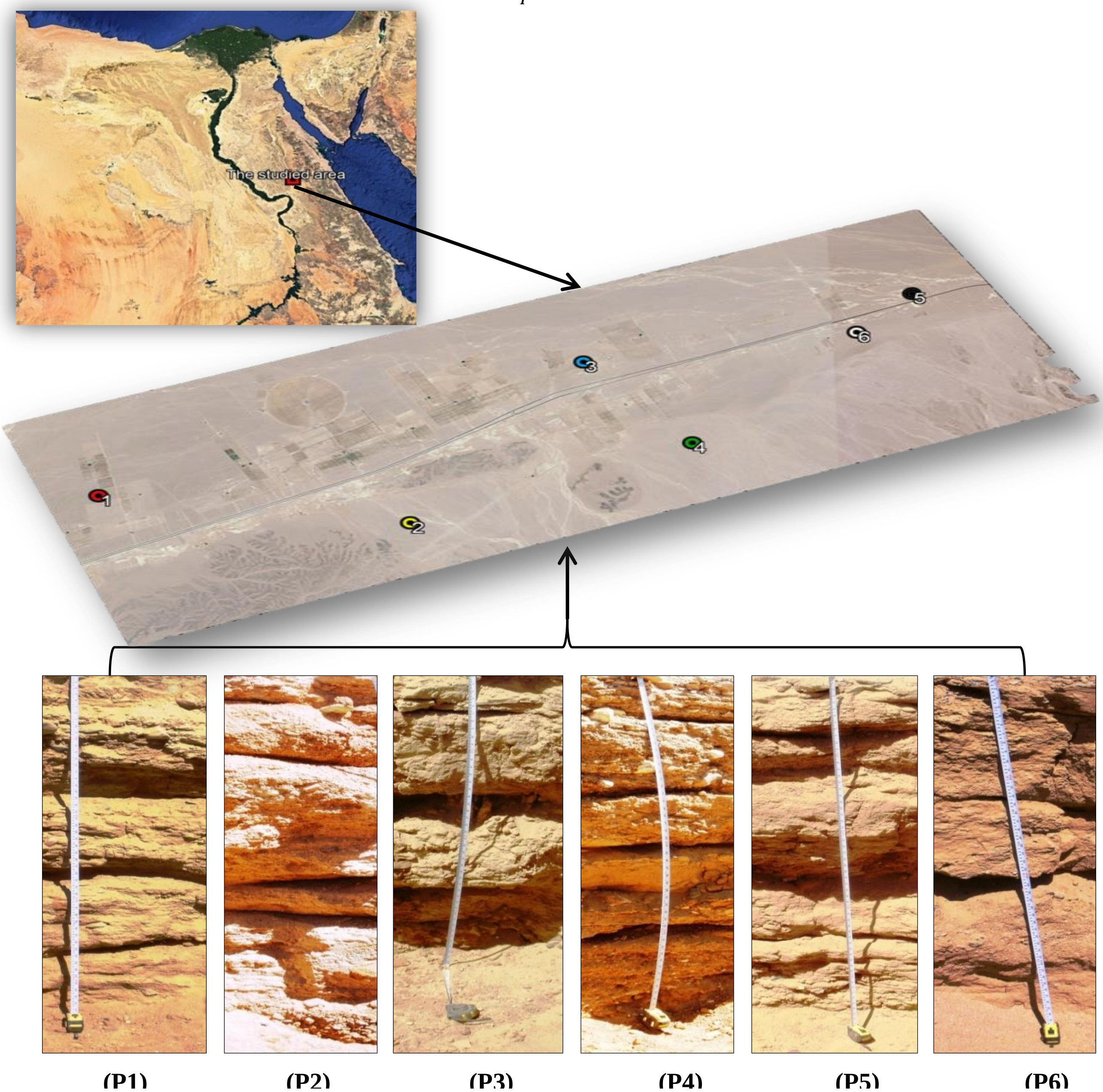

Figure.1. Location map of the studied site, soil profiles' locations, and collected soil profiles.

Land Capability evaluation

(i) Storie Index

The Storie index (Storie, 1954) is written as expressed in equation (2), relying on three factors, e.g. soil profile (A), the texture of surface soil (B), and a miscellaneous land factor including drainage, slope, and alkalinity (C). Factor X can be considered related to miscellaneous soil parameters that can be modified by management. These parameters are nutrients status, alkali status, pH-level, soil erosion, and micro-relief.

Each factor is scored as a percentage but multiplied as a decimal. The final index is expressed as a percentage. Where more than one property is considered, as in factor X, each is also scored as a percentage, and then all are multiplied together as decimals and expressed as the combined percentage of that factor. Storie regrouped the index values into six soil grades as shown in table (1).

$$I = A \times B \times C \times X \qquad (2)$$

Table.1. Soil grades of the Storie index.

Grade	Land quality	Soil rating (%)	Description
1	Excellent	>80 - 100	Suitable for a wide range of crops, including alfalfa, orchard, truck, and field crops.
2	Good	>60 - 79	Suitable for most crops, and expected yields are generally good to excellent.
3	Fairly good	>40 - 59	Generally of fair quality, though they have a less wide range of suitability than grades 1 or 2; they give good results with certain specialized crops.
4	Poor	>20 - 39	Have a relatively narrow range in their agricultural possibilities, in the sense that they may give good results for some crops but be unsuitable for other crops.
5	Very poor	>10 – 19	Very limited use except for pasture, mainly because of critical adverse conditions such as shallowness, roughness, and alkali levels.
6	Non-agricultural	<10	Unsuitable for any economic land use.

(ii) Sys and Verheye Index

Sys and Verheye (1975) proposed the following capability index (Ci) as expressed in equation (3) based on nine parameters for crop production in the arid and semi-arid regions.

$$Ci = A \times B \times C \times D \times E \times F \times G \times H \times I \qquad (3)$$

Where, A: soil texture, B: calcium carbonate, C: gypsum, D: salinity, E: sodium saturation, F: drainage, G: soil depth, H: weathering stage, and I: profile development.

Each factor is scored as a percentage but multiplied as a decimal. The final index is expressed as a percentage. Sys (1976) proposed the following scheme (table.2) for evaluating the degree of limitation. The limitation approach has been successfully used to provide a qualitative land evaluation based on general characteristics that are made available after a quality soil survey and general study of other soil resources in the area.

Table.2. Grades of soil and its limitations depending on the Ci score.

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Grade	Soil quality	Ci rating (%)	Limitations	Description
0	Optimal	>80	No.	Suitable for all agricultural purposes.
1	Near to optimal	60 - 80	Slight	Affect productivity for not more than 20%.
2	Moderate	45 - 60	Moderate	Influence on crop yield, benefits can still be made and the yield remains economical.
3	Poor	30 - 45	Severe	Decrease the yield below the profitable level; inhibit the use of the soil for the considered land utilization.
4	Very poor	<30	Very severe	Make the soil unsuitable for any economic land use.

Land suitability evaluation and classification

(i) The parametric method

This method was proposed by Sys *et al.* (1991); whereas soil-site parameters considered for land suitability evaluation are climatic data (i.e. available moisture or precipitation, temperature, and relative humidity), morphological characteristics of the soil profile (i.e. soil depth, slope, flooding, drainage and erosion level), Physical condition of the soil (i.e. soil texture, gravels, and Stoniness), and chemical parameters of soil (i.e. calcium carbonate, nutrient availability, gypsum, organic matter, cation exchange capacity, base saturation, salinity, alkalinity, and sodicity). Table (3) showed suitability classes and limitations of soils.

(ii) ALES model method

The Agricultural Land Evaluation of Suitability (ALES) model was developed by Ismail *et al.* (2001); whereas depends on using multi-criteria for evaluating the suitability of land. The same soil-site parameters mentioned above were used in the ALES model. The methodology of evaluating land suitability for different crops is illustrated in figure (2).

Land suitability classification

Table.3. Suitability classes and limitations.

Class	S1	S2	S3	N
Assignment	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Rating (%)	≥ 85	≥ 60 and < 85	≥ 40 and < 60	<40
Limitations	1 = No	2 = Slight	3 = moderate	4 = Severe

Mapping of land-Capability and land-Suitability

The software Q-GIS (version 2.14.1) was used for generating maps of land-capability; and land-suitability for different crops. The IDW-Interpolation tool was applied for predicting unknown values of each mapped parameter.

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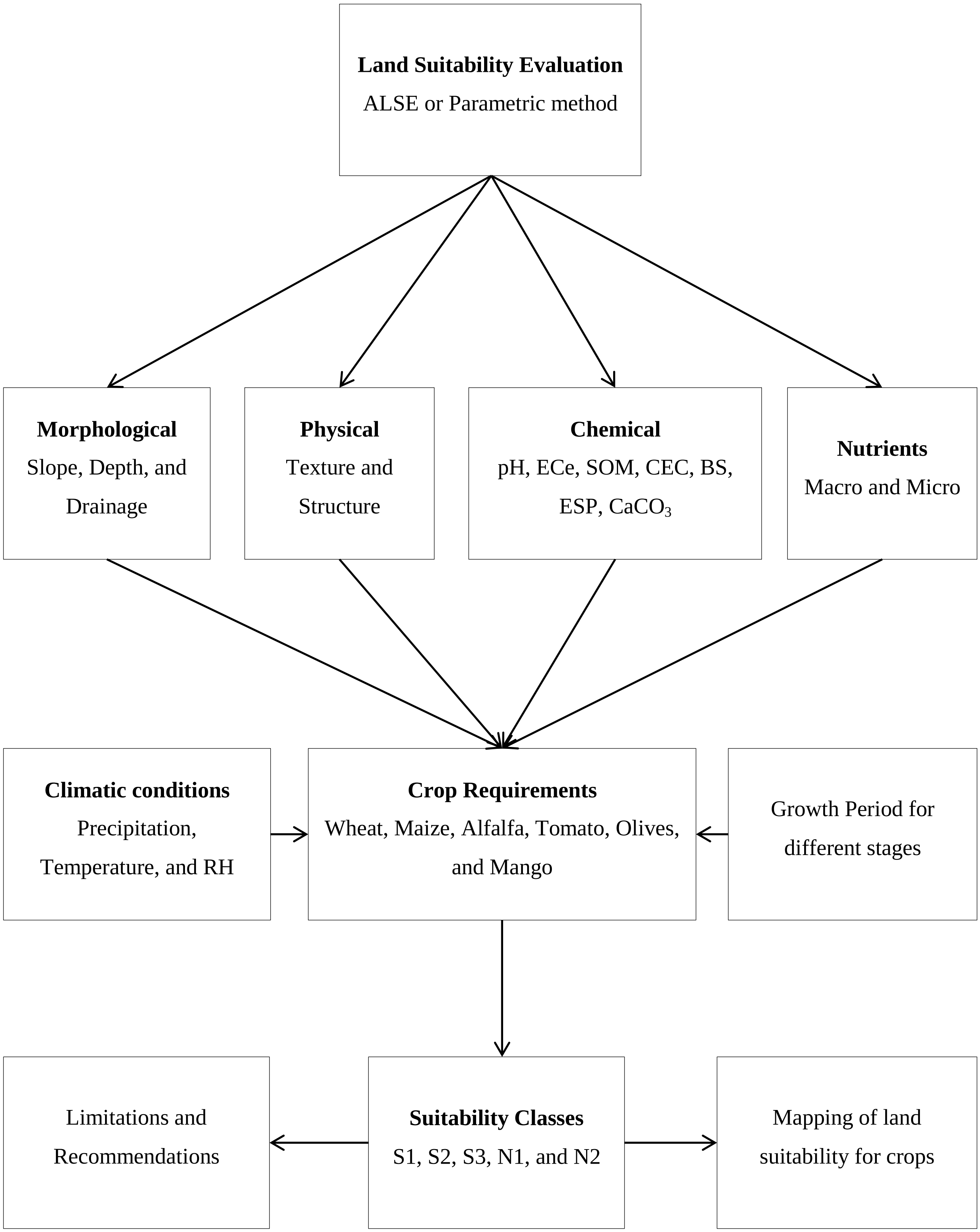

Figure.2. The methodology of evaluating land suitability for different crops.

3. RESULTS AND DISCUSSION

Soil characterization

Soils were analyzed for their physical, chemical, and fertility parameters and data are shown in table (4). Regarding morphological parameters of soil profiles, soil depth of all studied profiles was more than 120 cm which categorized as moderate to deep. The elevation of the studied site ranged from 185 to 355 meters above sea level. The slope in the site not exceeded 1%, and all soil profiles are well-drained soils. According to physical parameters, gravels percentage was less than 15% for all soil profiles, except P6 is around 20%. These soils have coarse texture; whereas loamy-sand (LS) texture was recorded for profiles (P1, P4, and P5), while sand (S) texture was in (P2, P3, and P6). Bulk density average is 1.40 $g.cm^3$, and wilting point (WP), field capacity (FC), and available water (AW) contents were very low. Chemical parameters were estimated for all soil profiles of the studied site. Soils are slightly-alkaline and ranged from slightly-saline to moderately-saline. Soil organic matter is low (>0.5%), and calcareous ($CaCO_3$ ranged from 4 to 15%). The CEC is low which ranged from 2.19 to 5.23 cmol $(p+).kg^{-1}$. The exchangeable basic cations were Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+}, respectively as dominancy in soil. The base saturation is high (more than 85%), while ESP is low (less than 15). Regarding the nutrients status in soil, available N, and P were low, while available K ranged from low to high in content. The studied soils were deficient for Fe, Mn, and Zn. However, available copper might be adequate for crop production. Figure (3) showed the thematic maps of the spatial distribution of some important soil parameters of the studied area.

Land capability evaluation

(i) Storie Index

The obtained results of land capability evaluation using the Storie index is shown in table (5). The soils of the studied area were categorized into two grades G3 and G4. The soils of profiles (P1, P4, and P5) were under grade 3; whereas these soils are fairly good quality land. Soils are rating between 40 and 59%. The suitability of these soils for cultivating with different crops is moderate; and they may give good results with certain specialized crops. On the other hand, the soils of profiles (P2, P3, and P6) were under grade 4; whereas these soils are poor-quality land. Soils are rated between 20 and 39%. They have a relatively narrow range in their agricultural possibilities, in the sense that they may give good results for some crops but be unsuitable for other crops. Figure (4) showed the land capability map of the studied area as a resulted of using Storie index rating data.

(ii) Sys and Verheye Index

Land capability evaluation data using this method is shown in table (6). The soils of the studied area were evaluated to be three grades (G3, G4, and G5). Soil profiles (P1 and P5) are under grade 3; whereas fairly good quality land, while soil profile (P4) is under grade 4 which poor quality. Soil profiles (P2, P3, and P6) are under grade 5; whereas very poor quality lands. Figure (5) showed a land capability map of the studied area as a resulted of using Sys and Verheye index rating data.

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Table.4. Soil characterization of the studied profiles.

Soil parameter	P1	P2	P3	P4	P5	P6
Latitudes (N)	26°.692	26°.688	26°.714	26°.701	26°.725	26°.719
Longitudes (E)	32°.771	32°.807	32°.826	32°.839	32°.865	32°.858
Morphological parameters						
Soil profile depth (cm)	130^+	130^+	120^+	130^+	120^+	120^+
Elevation (m.a.s.l)	185-215	222-232	236-251	260-277	268-301	302-355
Slope (%)	0-1	0-1	0-1	0-1	0-1	0-1
Drainage	Well	Well	Well	Well	Well	Well
Physical parameters						
Gravels (%)	5.17	5.63	8.26	6.77	9.71	19.81
Sand (%)	83.83	90.80	91.73	84.56	87.78	89.82
Silt (%)	10.52	3.72	4.07	10.21	7.66	6.03
Clay (%)	5.65	5.48	4.20	5.23	4.56	4.15
Texture	LS	S	S	LS	LS	S
D_b ($g.cm^{-3}$)	1.43	1.39	1.40	1.42	1.40	1.42
W.P. (v/v %)	7.28	1.29	1.48	6.81	3.78	2.94
F.C. (v/v %)	18.12	7.56	7.44	17.73	11.20	8.76
A.W. (v/v %)	10.84	6.27	5.96	10.91	7.43	5.82
Chemical parameters						
pH	8.15	8.22	8.15	8.09	8.08	8.14
ECe ($ds.m^{-1}$)	7.63	7.16	7.11	8.51	7.94	7.25
SOM (%)	0.31	0.30	0.21	0.23	0.25	0.19
$CaCO_3$ (%)	14.57	4.06	6.16	8.72	9.71	9.56
CEC cmol (p+).kg^{-1}	5.23	2.36	2.19	4.32	3.85	2.97
Exchangeable Na^+ cmol (p+).kg^{-1}	0.32	0.24	0.21	0.36	0.34	0.24
Exchangeable K^+ cmol (p+).kg^{-1}	0.48	0.20	0.16	0.25	0.23	0.17
Exchangeable Ca^{+2} cmol (p+).kg^{-1}	2.40	1.09	1.11	2.35	2.08	1.54
Exchangeable Mg^{+2} cmol (p+).kg^{-1}	1.37	0.44	0.44	1.11	0.75	0.60
B.S. (%)	87.71	84.81	88.65	90.55	85.23	84.54
ESP (%)	6.12	10.17	9.59	8.33	8.83	8.08
Macro and Micro-nutrients						
Available N ($kg.ha^{-1}$)	11.05	6.25	4.63	8.44	10.20	5.90
Available P ($kg.ha^{-1}$)	6.04	3.21	3.80	4.96	5.90	3.80
Available K ($kg.ha^{-1}$)	590	229	200	326	322	216
Available Fe ($mg.kg^{-1}$)	2.43	2.50	2.11	2.43	2.15	1.46
Available Mn ($mg.kg^{-1}$)	0.65	0.36	0.41	0.49	0.43	0.49
Available Zn ($mg.kg^{-1}$)	0.25	0.31	0.31	0.28	0.32	0.29
Available Cu ($mg.kg^{-1}$)	0.27	0.23	0.30	0.27	0.29	0.30

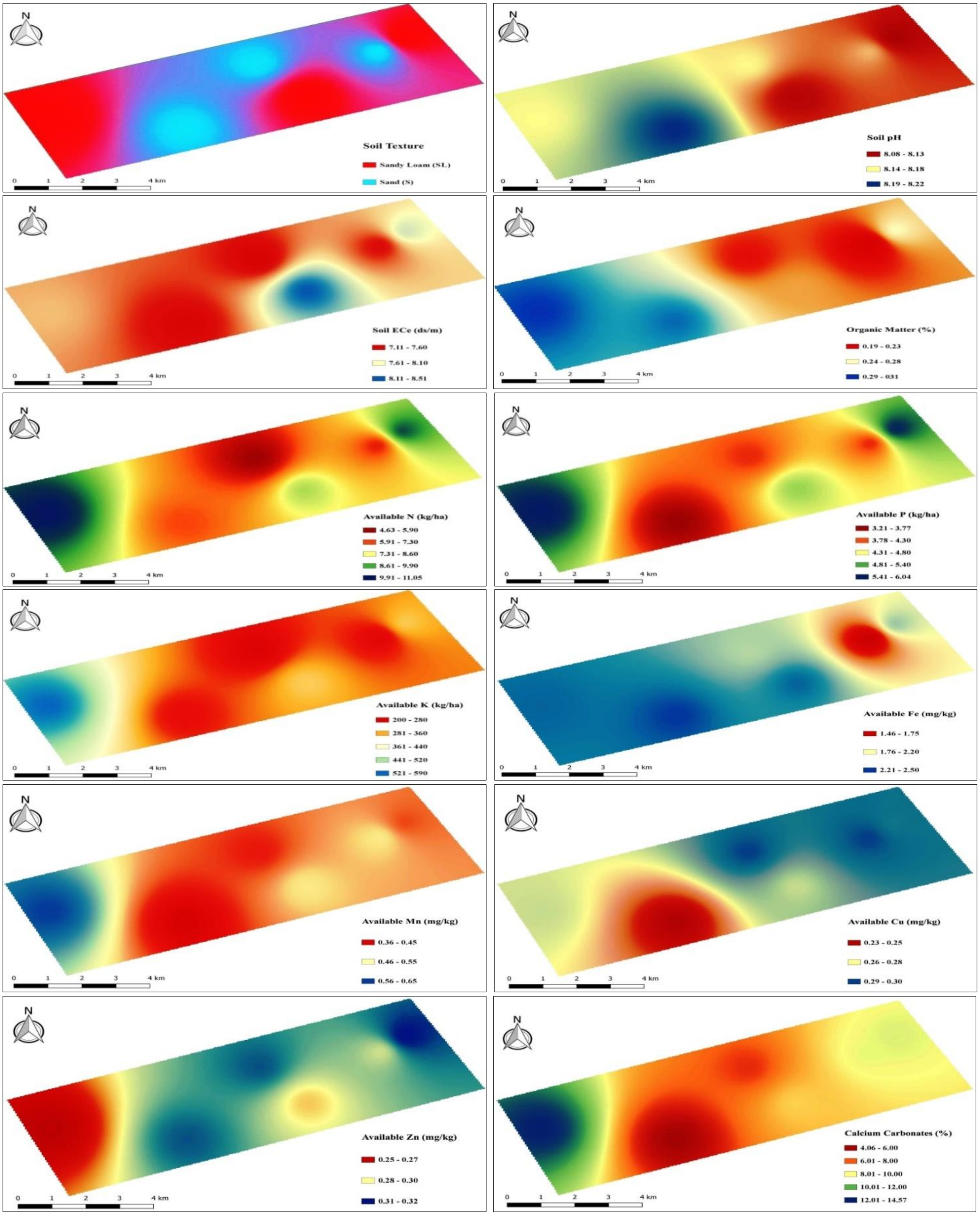

Figure.3. Thematic maps of spatially distributed soil parameters.

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Table.5. Land capability evaluation using the Storie index.

Soil parameter	Factor	P1	P2	P3	P4	P5	P6
Soil profile development	A	100	100	100	100	100	100
Texture	C	80	60	60	80	80	60
Slope (%)	X	100	100	100	100	100	100
Drainage		100	100	100	100	100	100
Nutrients status		85	80	80	85	80	80
Alkali status		100	100	100	100	100	100
pH-level		80	80	85	85	85	80
Erosion		90	90	85	85	80	80
Micro-relief		100	100	100	100	100	100
Storie Index score		48.96	34.56	34.68	49.13	43.52	30.72
Land capability Grade		G3	G4	G4	G3	G3	G4

Table.6. Land capability evaluation using Sys and Verheye index.

Soil parameter	P1	P2	P3	P4	P5	P6
Soil Texture (A)	65	25	25	65	65	25
Soil Depth (B)	100	100	100	100	100	100
Calcium Carbonates (C)	100	95	95	95	95	95
Gypsum (D)	-	-	-	-	-	-
alkalinity and Salinity level (E)	90	80	80	70	90	90
Drainage (F)	100	100	100	100	100	100
Slope (G)	100	100	100	100	100	100
Land Capability index score	58.50	19.00	19.00	43.23	55.58	21.38
Capability class	G3	G5	G5	G4	G3	G5

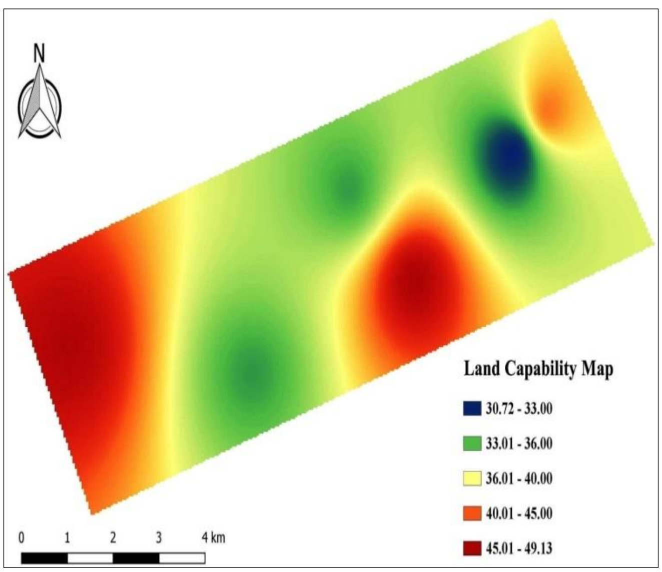

Figure.4. Land capability maps of the Storie index.

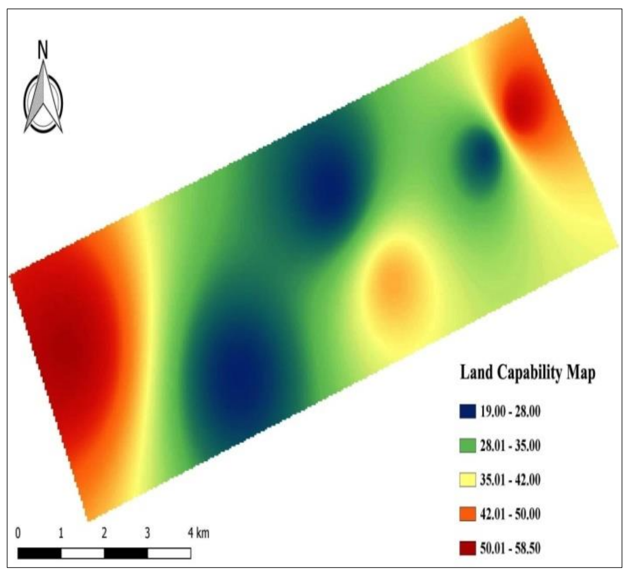

Figure.5. Capability map of Sys and Verheye index.

Land suitability evaluation

The suitability of studied area soils was evaluated for different soil crops (i.e. Wheat, Maize, Alfalfa, Tomato, Olives, and Mango). The results of two used methods of suitability evaluation (parametric method and ALES) are shown in table (7). The results obtained from parametric method showed that the soils of profiles (P1 and P4) are moderately-suitable (S2) for all studied crops, while soils of profiles (P3, P5, and P6) are marginally-suitable (S3) for Wheat crop and moderately-suitable (S2) for the other studied crops. Soils of profile (P2) are marginally-suitable (S3) for Wheat and Maize crops and moderately suitable (S2) for the rest crops. Regarding the obtained results from the ALES model, soils of profiles (P3 and P4) are non-suitable (N1), while other soils are marginally-suitable (S3) for Wheat and Maize crops. All soil profiles are marginally-suitable (S3), except (P2 and P5) which moderately-suitable (S2), for Alfalfa crop cultivation. All soils are marginally-suitable (S3) except soils of profile (P1) which non-suitable (N1) for cultivating Tomato. Regarding Olive crop, all soil profiles are marginally-suitable (S3), except (P1 and P6) which moderately-suitable (S2). Soil profiles (P1, P4, and P5) are marginally-suitable, while the rest soil profiles are moderately-suitable (S2) for cultivating Mango trees. Figure (6) showed the land suitability maps for different crops in the studied area using the data of the parametric method. The limitations of these soils ranged from slight to moderate limitations. These limitations are soil texture, soil salinity, and soil organic matter content. These parameters can be enhanced through the addition of soil organic materials and mixing the surface soil (0-25cm) with clay or organic soils.

Table.7. Land suitability evaluation using the parametric method and ALES model.

Crop	Suitability Classes					
	P1	P2	P3	P4	P5	P6
Parametric method - Sys *et al.* (1992)						
Wheat	S2 (60.94)	S3 (57.19)	S3 (58.75)	S2 (60.93)	S3 (59.69)	S3 (58.13)
Maize	S2 (63.53)	S3 (59.12)	S2 (60.29)	S2 (63.52)	S2 (63.23)	S2 (60.29)
Alfalfa	S2 (69.69)	S2 (65.00)	S2 (66.25)	S2 (68.44)	S2 (70.31)	S2 (66.25)
Tomato	S2 (63.44)	S2 (63.43)	S2 (62.82)	S2 (63.44)	S2 (63.13)	S2 (63.13)
Olives	S2 (77.50)	S2 (76.25)	S2 (76.25)	S2 (77.50)	S2 (77.50)	S2 (75.62)
Mango	S2 (68.75)	S2 (67.81)	S2 (67.18)	S2 (67.81)	S2 (69.38)	S2 (66.25)
ALES model – Ismail *et al.* (2001)						
Wheat	S3	S3	N1	N1	S3	S3
Maize	S3	S3	N1	N1	S3	S3
Alfalfa	S3	S2	S3	S3	S2	S3
Tomato	N1	S3	S3	S3	S3	S3
Olive	S2	S3	S3	S3	S3	S2
Mango	S3	S2	S2	S3	S3	S2

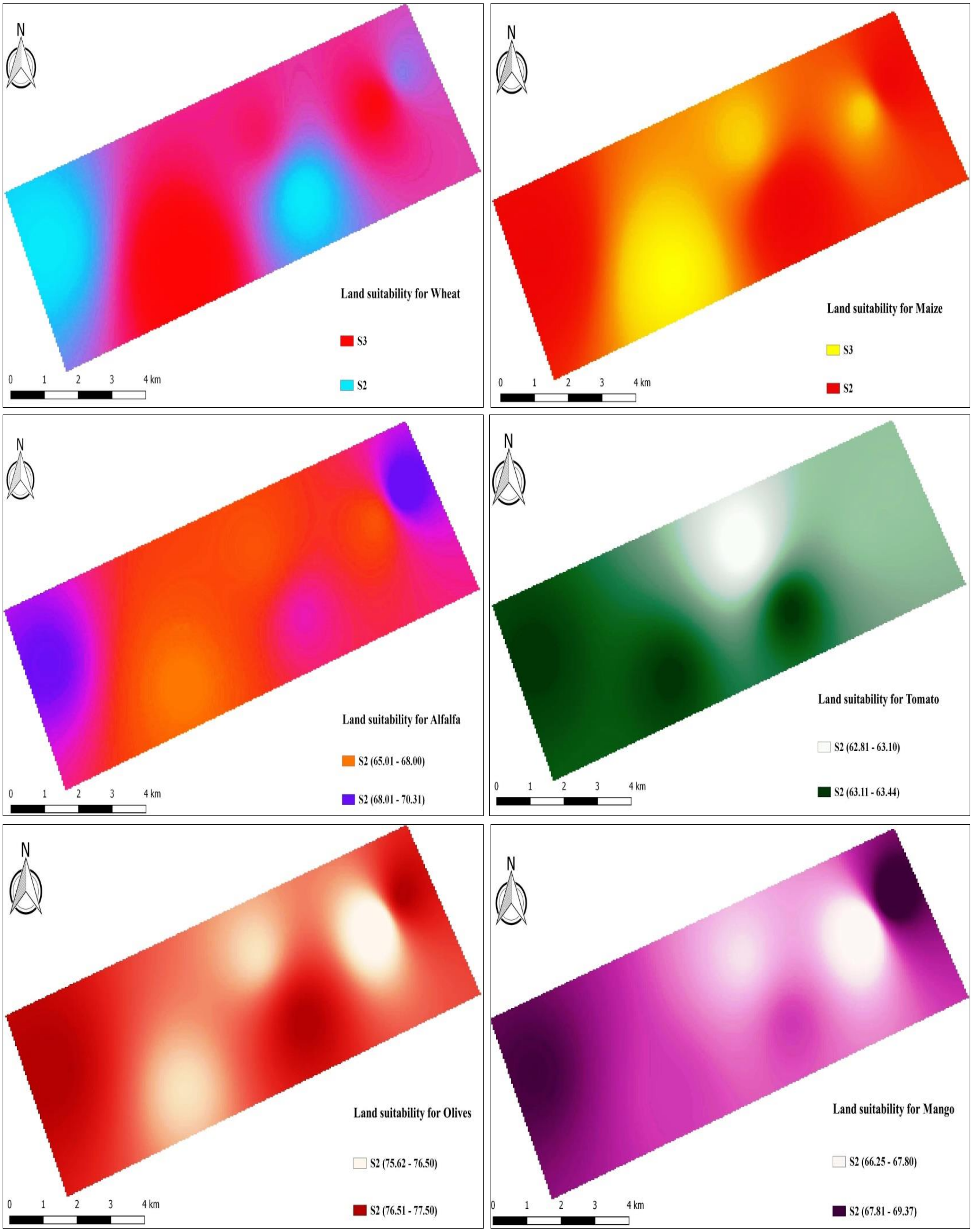

Figure.6. Land suitability maps for different crops.

4. CONCLUSION

Different indices such as the Storie index; and Sys and Verheye index were used to evaluate the land capability of the studied site. The parametric method as well as the ALES method of land suitability evaluation and classification was used. The soils of the studied area ranged between poor and fair in quality. These soils ranged from marginally-suitable to moderately-suitable for cultivating major crops. The limitations of these soils are soil texture, soil salinity, and soil organic matter content. The integration between GIS tools, methods of assessing land capability, and also suitability is important for better utilization of land to achieve higher agricultural productivity.

5. REFERENCES

Abd El-Kawy, O.R., Ismail, H.A., Rod, J.K. and Suliman, A.S. (2010) A Developed GIS-based Land Evaluation Model for Agricultural Land Suitability Assessments in Arid and Semi-Arid Regions. *Research Journal of Agriculture and Biological Sciences* 6 (5): 589-599.

Awad A. 2008. Integration of remote sensing, geophysics, and GIS to evaluate groundwater potentiality: A case study in Sohag region, Egypt. *The 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum*.

Black C A. 1982. *Methods of soil analysis-Part2, chemical, and microbiological properties*. Agronomy series no. 9, ASA, SSSA, Madison, Wis., USA.

El-Shamy I Z. 1988. Quantitative geomorphometry and surface runoff control for Wadi Qena, Eastern Desert. E.G.S. *Proceedings of the 6th Ann. The meeting*, pp.13-26.

El-Zawahry A E, El-Gamal M H, and Emam Y. 2004. Developing renewable groundwater resources in arid lands pilot case: The Eastern Desert of Egypt. *Hydrological modeling tasks* **3:**29-32.

FAO. 2006. *Guidelines for soil description* (4th ed.), FAO, Rome, 95p.

FAO. 1976. *A Framework for land evaluation*: Soils Bull.32, Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

Ismail, H.A., Morsy, I.M., El-Zahaby, E.M., and El-Nagar, F.S. (2001) A Developed expert system for land use planting by coupling and modeling. *Alex. J. Agric. Res*. 46 (3): 141-154.

Jackson M L. 1969. *Soil chemical analysis-advanced course*. 2nd edition published by the author, Dept. of Soil Sci., Univ. of Wisconsin, Madison, USA.

Jackson M L. 1973. *Soil chemical analysis*. Prentice-Hall of India Private Limited, New Delhi, India.

Lindsay, W.L., Norvell, W.A., 1978. Development of DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc. Am. J*. 42, 421–428.

Panigrahy, S., Manjunath, K.R., and Ray, S.S. (2006) Deriving cropping system performance indices using remote sensing data and GIS. *Int. J. Remote Sensing* 26, 2595–2606.

Saxton K E and Rawls W J. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Journal of Soil science society of America* **70**:1569–1578.

Storie, R.E. 1954. *Land classification as used in California*. Fifth Int. Soil Conf. Leopoldville.

Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* **25**:259-260.

Sys, C., 1976. *Land Evaluation*. ITC, State Univ., Ghent, Belgium.

Sys, C., and Verheye, W. 1975. *Principles of land classification in arid and semi-arid regions*. ITC, State Univ., Ghent, Belgium.

Sys, Ir. C., Van Ranst, E. and Debaveye, J. Ir. 1991.*Methods of land evaluation.* Training Center (ITC) for post-graduate soil scientists (part II). Univ., Ghent, Belgium.

Sys, C., Van-Ranst, E., and Debaveye, J. 1993. *Land evaluation*, part III: Crop requirements. Int. Training Centre (ITC) for Post-Graduate Soil Scientists. Ghent University, Ghent, Belgium.

Walkley A and Black I A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil science* **37**:29-38.

Whatanable FS and Olsen S R. 1965. Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extract from the soil. *Proc. Soil Science Society of America* **29**:677-678.