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Evaluation of Land Capability and Suitability Using Asle Program and Gis Techniques: A Case Study on Some Soils of East Nile Delta, Dakahlia Governorate, Egypt.

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ABSTRACT

The aim of the study was to evaluate the land capability and suitability for some crops through determining soil physical, chemical properties and fertility in some soils of East Nile Delta in Dakahlia Governorate by using ASLE program and GIS techniques. ASLE program was used for calculating land capability and suitability for some field crops, vegetables crops and fruit trees with a total of 15 crops. For this purpose, 15 soil samples were randomly distributed within the studied area at a depth of (0-30, 30-60 and 60-90cm), which were subjected to physical and chemical analyses. Results indicate that the studied area was classified into two soil classes (i) excellent-C1 and (ii) good-C2. While, the land capability was fit into two classes: I- C2 (good) and II- C3 (fair). Concerning land suitability, studied crops can be grown in these soils. These crops were classified according to land suitability of studied area into three classes: (i) S=very suitable (wheat, rice, maize, sugar beet, alfalfa, barley, faba bean, pea, cotton, potato, grape, and citrus), (ii) S3= moderately suitable (tomato) and S4= marginally suitable (onion and pepper). The suitable field crops could be arranged by preference as: sugar beet > wheat > rice > barley > maize > faba bean > cotton > alfalfa > onion. While vegetables crops arranged by preference as: pea > potato > tomato > pepper > onion. Meanwhile, grape was the optimum fruit trees followed by citrus.

Keywords: Land capability evaluation, land suitability, crops, ASLE, GIS.

INTRODUCTION

Land capability and suitability assessment as a requirement for sustainable agriculture is critical important, which determines current and future potential of any area (Tesfay *et al* 2017). Land evaluation is a prediction process of land use which based on its characteristics, where a variety of analytical models can be used in these predictions, ranging from qualitative to quantitative (Rossiter, 1996). Land evaluation may be concerned with land current contribution; also it is only part of the process of land use planning. Land suitability is a classification process of soil to use them appropriately. This process is the evaluation and grouping of specific areas of land in terms of their suitability for defined uses according to FAO (1976, 1983 and 2006). The principle purpose of land capability evaluation is prediction with the potentiality and constrain of land for changing use. Land suitability is the process of estimating the potential of land for alternative kinds of uses. This could guide us for new management practices or the introduction of a fully new land use types (Dent and Young, 1981). Also this could guide us to make effective decisions to achieve optimum land productivity and to ensure environmental sustainability(Kurtener *et al.* 2008). There are direct or indirect methods to evaluate land capability. Direct methods are carried out in the field or laboratory by using some experiments under given climatic and management conditions. While indirect evaluations are done using models of varying complexity to estimate land productivity (Dengiz and Sağlam 2012). Land evaluation can tell farmers how suitable their land is in terms of soil limitations to specified land use and management practices. Land suitability evaluation analysis is necessary to achieve optimum management and utilization of available land resources for sustainable agricultural crop production (Jimoh *et al.* 2018). Land, water and soil are precious natural resources whose proper use affects the life supporting systems. Sustainable development cannot be successful without proper conservation of natural resources. However, management of land resources is inevitable for both continued agricultural productivity and protection of the environment. Additionally the sustainable development of any area needs to require a scientific basis to maintain harmony with environment. (Panhalkar *et al.* 2014).

Limitation factors for land capability were increment of soil salinity and low levels of organic matter content and NPK. Land suitability of crops in this soils was for barely, wheat, sugar beet, sunflower, cotton and rice; while not suitable for pepper, olive, fig and peanut (Zamil *et al* 2009). According to Digby Wells Environmental (2015), the conventional methods were focused on studying spatial variability among soil properties and reporting these variations in soil survey reports. On the other hand, the current methods depend on computer science systems for land evaluation. These systems integrate information about soil physical, chemical and fertility characteristics to evaluate land capability and suitability. In this regard ASLE is one of the examples of land evaluation systems.

ASLE–Applied System for Land Evaluation- computer program is used to evaluate land capability and suitability (Ismail and Morsi, 2001, Ismail *et al.* 2001). This model calculates the final land capability index as a percentage value and land suitability based on four indices; soil properties, irrigation water quality, soil fertility factors and environmental conditions. Each factor was described as an index value to give its statues in the percentage form (Marei *et al* 1987, Zamil *et al* 2009). ASLE program works compares the characteristics and interactivity of the land unit to evaluate land capability class (C1-Excelent, C2-Good, C3-Fair, C4-Poor, C5-Very poor and C6-Non agriculture) and land suitability class (S1-Very suitable, S2-Suitable, S3-moderately suitable, S4- arginally suitable, N1-currently unsuitable and N2-permanently unsuitable) (Sayed *et al.* 2016).

The objectives of this study were to evaluate land capability of some soils East Nile Delta in Dakahlia Governorate -Al-Sembelawaan and Temai Elamded districts- and to evaluate suitability for some potential crops for these soils using ASLE model and GIS techniques.

MATERAILS AND METHODS

Soil sample preparation:

The area is located between 31◦ 19´ to 31◦ 41´ E 30◦ 48´ to 30◦ 59´ N at East Nile Delta (Temai El-amded district - about 126 km^2 and Al-Sembelawin district - about 304 km^2) in Dakahlia governorate, Egypt (Fig. 1). Fifteen soil profiles representative were dug throughout the studied area. Soil samples were collected from each soil profile at three consequent depths (0-30, 30-60, and 60-90cm), which coordinates of samples locations. The samples were recorded using the Global Positioning System (GPS) (Fig. 1). Samples were air-dried, crushed and sieved through a 2mm screen and the fine earth (less than 2mm diameter) was used for physical and chemical analyses.

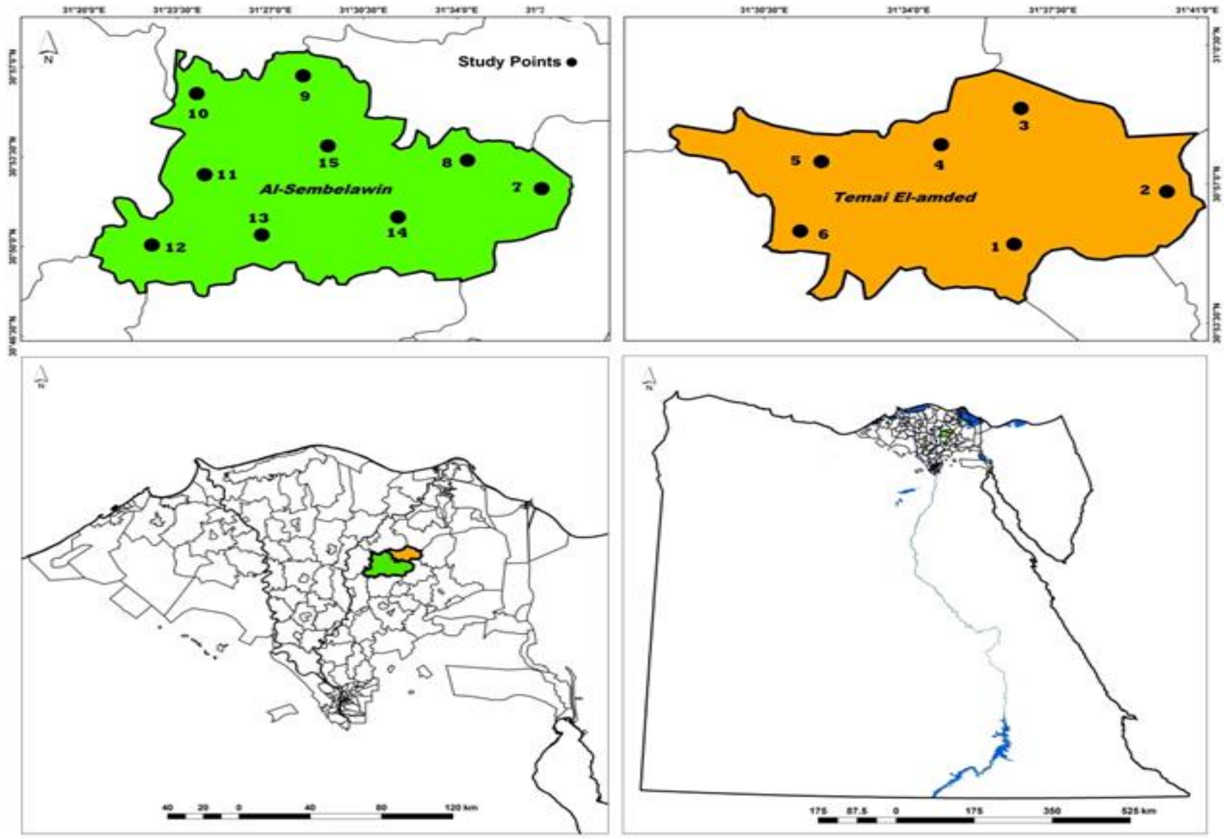

Figure 1. Location map of the study areas and spatial distribution of soil profiles.

Determination of soil physical and chemical properties

Physical analyses of soils samples:

Particle size distribution was performed according to Piper (1947). Bulk density was carried out according to Dewis and Freitas (1970). Total soil porosity was calculated according to the formula: Porosity = (1 - Db/ Dr)*100 Where, Db is soil bulk density (g cm^{-3}) and Dr is soil real density (2.65 g cm^{-3}). Saturation percentage was carried out according to Richards (1954).

Chemical analyses of soils samples:

OM was determined by Walkley and Black method as described by Hesse (1971). EC was measured in the soil paste extract using the EC meter as described by Hesse(1971). CEC and Exchangeable cations were determined as described by Hesse (1971). Available nitrogen in the soil was extracted in the 2.0 M KCl according to Hesse (1971) and determined by micro-kjeldahl apparatus. Soil pH is measured according to Jackson (1967). Available P is measured according to Olsen and Sommers (1982). Total nitrogen (TN) was calculated according to the formula: TN = 0.026 + 0.067 x OC (Rashidi and Seilsepour, 2009). $CaCO_3$ was carried out according to Piper (1947).

Chemical analyses of water sample:

Soluble cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions ($CO3^{2-}$, $HCO3^-$, and Cl^-) according to Jackson (1967). SAR was calculated according to the formula: $SAR = Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$ Cations are in $meqL^{-1}$. Na % was calculated according to the formula: $(Na^+ \times 100) / (Ca^+ + Mg^{+2} + Na^+)$ (Richards, 1954). RSC was calculated according to the formula: $RSC = (CO3^{-2} + HCO3^-) - (Ca^{+2} + Mg^{+2})$.

Land capability and suitability evaluation:

Evaluation of land capability and suitability was carried out using ASLE (The Applied System of Land Evaluation) software according to Ismail and Morsi, (2001). It works as an extension under ArcGIS software package. Several soil physical, chemical and fertility properties are integrated in this model. The outputs are also displayed in simple maps that represent the spatial variability in each of the obtained indices and land suitability for certain crop all over the studied area. Table 1 shows the ranges for land capability and suitability classes according to Storie (1933 and 1944). The flowchart of the program is illustrated in Fig. 2.

Table 1. Ranges for land capability and suitability classes according to Storie (1933 and 1944)

Class	Land capability Class	Range (%)
C1	Excelent	> 80
C2	Good	60 - 80
C3	Fair	40 - 60
C4	Poor	20 - 40
C5	Very poor	10 - 20
C6	Non agriculture	< 10
Class	Land suitability Class	Range (%)
S1	Very suitable	> 80
S 2	Suitable	60 - 80
S 3	Moderately suitable	40 - 60
S 4	Marginally Suitable	20 - 40
N1	Currently unsuitable	10 - 20
N2	Permanently unsuitable	< 10

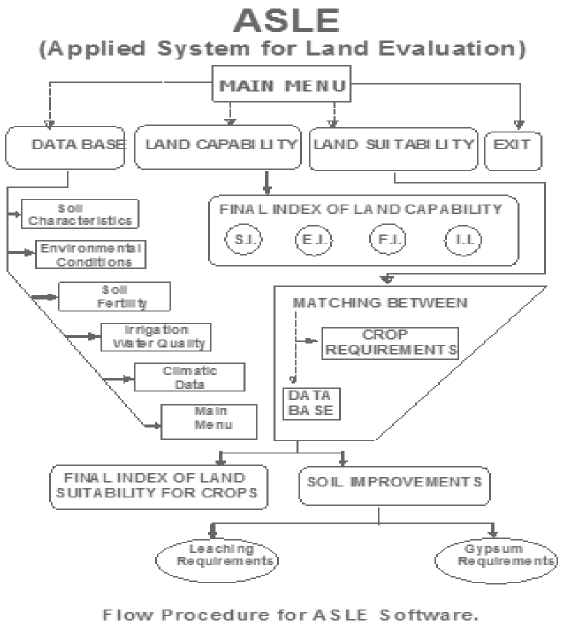

Figure 2. Flow chart of land evaluation program (ASLE).

Statistical analysis

Descriptive statistics for the ranges, averages, Standard deviations (STDEV) and Coefficient of Variation (C.V) of soil properties of the studied area were performed using Microsoft Excel Software (version 2010, Microsoft Corporation, USA).

RERSULTS AND DISCUSSION

Soil physical properties:-

Descriptive statistics for the ranges, averages, (STDEV) and (C.V) of some soil physical properties of the studied area are given in Table 2. These properties include: coarse and fine sand, silt, clay, saturation percentage, Bulk Density and Porosity. Average values of coarse sand and fine sand in the studied soils were 7.44 and 26.16 %; while averages of silt and clay percentage were 31.13 and 35.88 %, respectively. The majority of soil textures in the studied area were Clay loam. Average of saturation percentage was 65.17 %. Saturation percentage values were associated with clay content in the studied soils. Bulk density and porosity averages were 1.14 g cm^{-3} and 57.10 %, respectively.

Table 2. Ranges of soil physical properties in the studied soil area.

Property	Unit	Min.	Max.	Average	STDEV[1]	C.V[2]
Coarse Sand	%	0.77	32.3	7.44	7.62	102.40
Fine Sand	%	9.74	49.66	26.16	11.65	44.53
Silt	%	15.16	54.95	31.13	10.97	35.24
Clay	%	11.72	61.15	35.88	13.02	36.28
Soil Texture		Clay loam			--	--
Saturation percentage	%	37.55	85.17	65.17	11.23	17.23
Bulk Density	gcm^{-3}	0.97	1.51	1.14	0.15	13.301
Porosity	%	43.02	63.40	57.10	5.71	9.99

[1]**Standard Deviation** [2]**Coefficient of Variation**

Soil chemical properties

Data in Table 3 show the ranges, average values, Standard deviations (STDEV) and Coefficient of Variation (C.V) of some soil chemical properties of the studied area. These properties include soil pH, Electrical conductivity, exchangeable cations, cation exchange capacity, exchangeable sodium percentage, Organic matter and calcium carbonate. Average of pH and EC values were 8.17 and 1.96 dSm^{-1}, respectively. These data indicate that the studied soils are ranging from non-saline (0.81 -1.20 dSm^{-1}) to slightly saline (1.61 -3.20 dSm^{-1}) according to Dahnke and Whitney, (1988). Salinization is one of the main factors affecting on soil agricultural productive capability (Prapagar *et al.* 2015). Average of EX. Ca^{2+}, Mg^{2+}, K^+ and Na^+ values were 26.3, 21.37, 1.01 and 2.06 cmol kg^{-1}, respectively. CEC average value was 50.60 cmol kg^{-1}. Total exchangeable cations and CEC are two significant concepts in soil fertility and long-term productivity (Hodges, 2010), while ESP average value was 4.00 %; which indicates that most of the studied soils were non sodic soils. Organic matter was low to medium in the studied soils with an average 0.91 % (Ravikumar and Somashekar, 2013). SOM is an important pool for nitrogen and carbon. In addition, SOM has a key-role in the physical properties of soil, especially soil bulk density. In this regard, high variation in climatic conditions, and its subsequent effect on soil OM will be associated with high variation in soil bulk density (Zamil *et al* 2009, Golabi, *et al.* 2004, Thomas *et al.* 2006, GÖL 2017). There was variability in calcium carbonate within the studied area, where calcium carbonate varied from 0.46 to 9.60 % with an average of 3.21%.

Soil fertility properties

Data in Table 4 show the ranges, averages, (STDEV) and (C.V) of available NPK, total nitrogen, organic carbon, C/N ratio and fertility index of the studied area. Averages of NPK values were 125.00, 6.19 and 288.00 mg kg^{-1}, respectively. Soil fertility evaluation of NPK indicate that N content was medium in some locations to high in others. Also content of P was low to medium, while K content was low to high in the studied area, These data indicates that some soils in the studied area need to apply NPK fertilizers (Hamissa *et al.* 1993). Total Nitrogen, organic carbon and C/N ratio average values were 0.27%, 0.53 % and 1.98, respectively. Average of fertility index-FI value was 56.45%. Fertility index was fit into 2 classes, which are I- Good (C2) and II-Fair (C3) according to Thomas *et al.* (2006).

Table 3.Ranges of soil chemical properties in the studied soil area.

Property		Unit	Min.	Max.	Average	STDEV	C.V
pH			7.66	8.70	8.17	0.31	3.84
EC		dSm^{-1}	0.67	3.55	1.96	0.84	42.63
Exchangeable Cations	Ca	$cmol\ kg^{-1}$	17.30	38.40	26.30	4.00	15.20
	Mg		14.65	27.55	21.37	3.34	15.62
	K		0.45	1.70	1.01	0.30	29.40
	Na		0.95	4.41	2.06	0.90	43.76
CEC		$cmol\ kg^{-1}$	41.60	57.90	50.60	3.9	7.72
ESP		%	2.06	8.34	4.00	1.50	37.43
Organic Matter		%	0.29	1.66	0.91	0.43	56.88
$CaCO_3$		%	0.46	9.60	3.21	1.95	60.89

Table 4. Ranges of available NPK, total nitrogen (TN) and C/N ratio in the studied soil area.

Property		Unit	Min.	Max.	Average	STDEV	C.V
Available NPK	N	($mg\ kg^{-1}$ soil)	64.88	199.50	125.00	33.57	26.85
	P		2.46	10.50	6.19	1.713	27.66
	K		115.00	486.00	288.00	92.10	32.00
TN		%	0.18	0.40	0.27	0.069	25.82
OC		%	0.17	0.96	0.53	0.25	46.70
C/N Ratio			1.14	3.10	1.98	0.56	28.10
Fertility Index		%	48.02	64.40	56.45	4.76	8.44
Fertility Class			C3	C2	- -	- -	- -

C2 Good C3 Fair

Final Land Capability Index

Data in Table 5 show the ranges, averages, (STDEV) and (C.V) of physical index, chemical index, soil index, soil class, final land capability index and final land capability class of the studied area. Physical index varied from 65.92 and 88.79 (average about 80.44); while average of chemical index was 96.57, (varied from 95.12 and 97.48). Soil index values varied from 63.76 and 85.74 (about 77.68 in average). According to the soil index - physical and chemical indices- the studied area were fit into two classes, which are I-excellent (C1) and II-good (C2). The water index varied from 95.32 and 100 (average about 98.59) and the environmental index varied from 64.86 and 82.58 (average about 75.51). Final land capability index values varied from 57.50 and 72.56 (about 65.32 in average). Final land capability class was fit into two classes which are I- good (C2) and II-fair (C3) as illustrated in Figures 3 and 4, (Thomas *et al.* 2006). Fig. 5 illustrates the comparative between Minimum, maximum, averages, STDEV and C.V of final index in both of studied area 1 and studied area 2. Fig. 6 shows the percentage of physical index, chemical index, soil index, water index, environmental index and final index in the studied soil areas. Fig. 7 illustrates some of the linear relationships between physical index, chemical index, soil index and fertility index and land index % in the studied soils. It is also observed that linear relationships between physical index, chemical index, soil index and Fertility index with and land index were significant correlations (r = 0.85, 0.35, 0.88 and 0.94, respectively).

Table 5. Ranges of physical index, chemical index, soil index, water index, environmental index and final land capability index of the studied area.

Profile No.	Physical Index	Chemical Index	Soil Index	Soil Class	Final Index	Final Class
1	76.24	96.16	73.32	C2	58.92	C3
2	80.79	96.57	78.01	C2	65.12	C2
3	88.79	96.56	85.74	C1	71.37	C2
4	81.09	95.50	78.68	C2	66.22	C2
5	80.22	96.30	76.68	C2	64.98	C2
6	83.62	97.45	81.48	C1	68.20	C2
7	77.29	97.28	75.19	C2	61.70	C2
8	81.42	96.62	78.67	C2	67.76	C2
9	85.60	97.08	83.11	C1	72.56	C2
10	86.98	95.12	82.73	C1	64.58	C2
11	87.52	96.08	84.09	C1	70.21	C2
12	75.05	95.47	71.65	C2	57.50	C3
13	82.73	97.10	80.32	C1	68.01	C2
14	69.95	96.43	67.45	C2	59.46	C3
15	81.99	96.77	79.34	C2	68.48	C2
Min.	69.95	95.12	67.45	C2	57.5	C3
Max.	88.79	97.45	85.74	C1	72.56	C2
Average	81.29	96.43	78.43	- -	65.67	- -
STDEV	5.10	0.68	4.972	- -	4.58	- -
C.V	6.28	0.71	6.34	- -	6.97	- -

C1 = Excellent C2 = Good, C3 = Fair

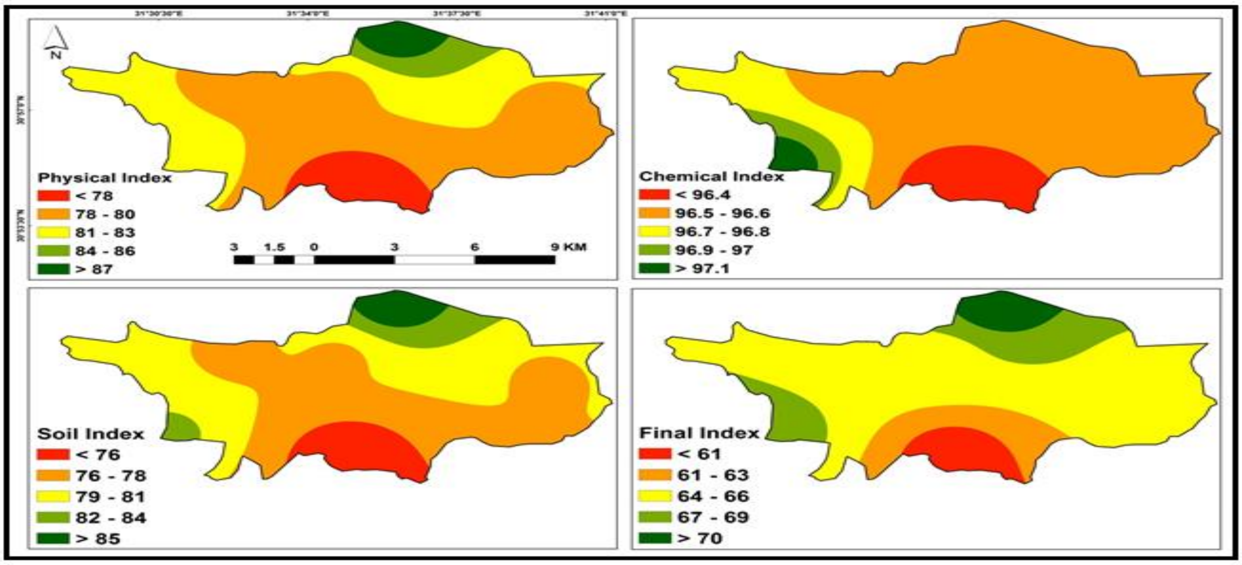

Figure 3. physical index, chemical index, soil index and final land capability index of the studied area 1.

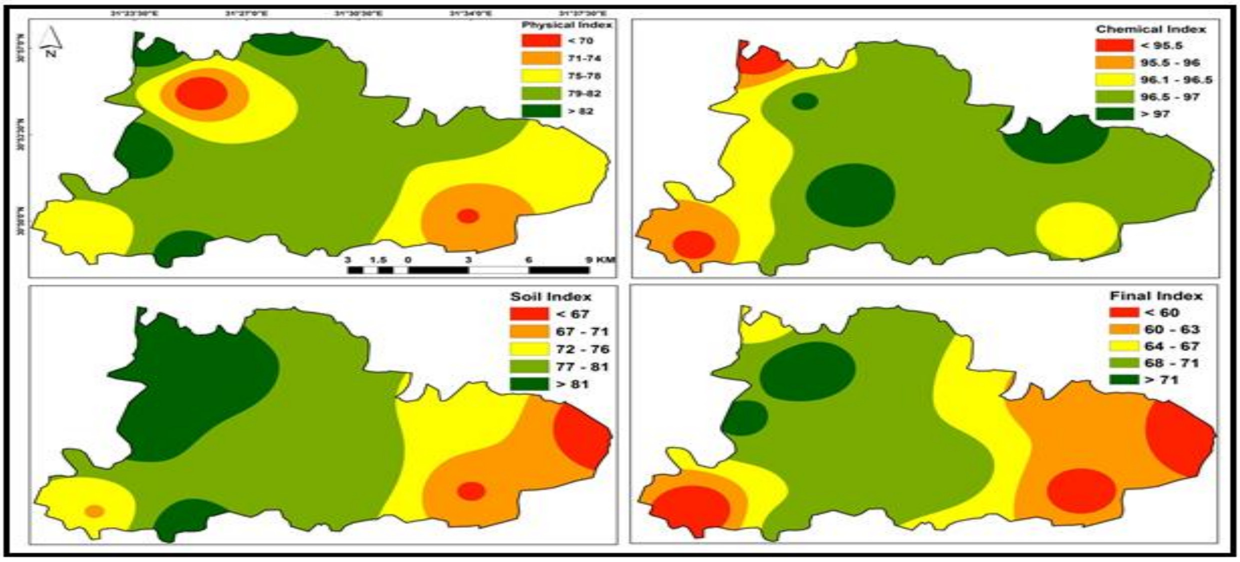

Figure 4. physical index, chemical index, soil index and final land capability index of the studied area 2.

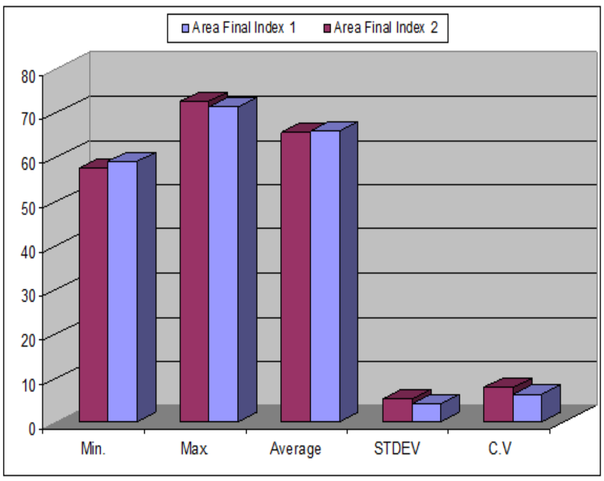

Figure 5. Comparative between minimum, maximum, averages, STDEV and C.V of final index in the studied soil area (area 1 and area 2).

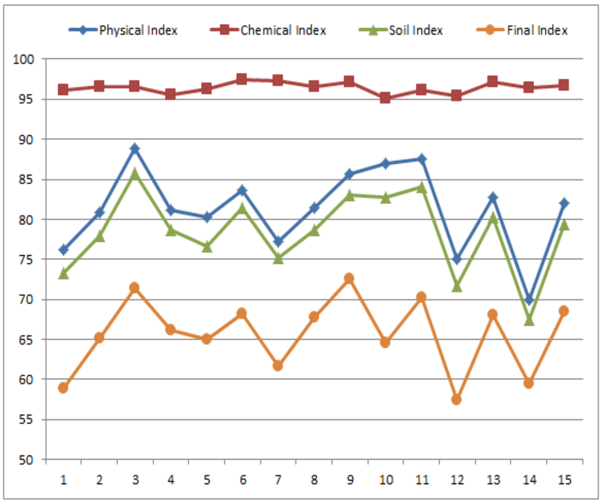

Figure 6. Percentage of physical index, chemical index, soil index and final index in the studied soil area.

Land Suitability:

ASLE model was used to evaluate land suitability of the studied soils for 15 crops (field crops, vegetables crops and fruit trees), which were classified into three categories as follows:

1- Field crops (wheat, rice, maize, sugar beet, alfalfa, barley and faba bean, cotton).
2. Vegetable crops (onion, pea, pepper, tomato and potato).
3. Fruit trees (grape and citrus).

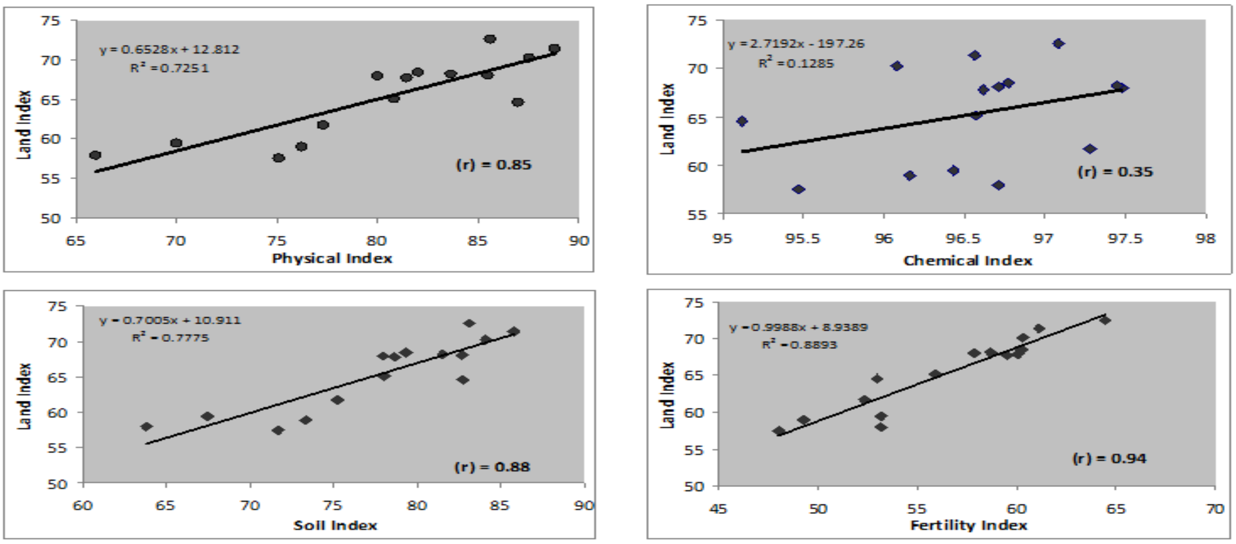

Figure 7. Linear relationships between physical index, chemical index, soil index and fertility index with land index % in the studied soils.

Table 7 and Figures 9-10 represent land suitability class and the percentage of land suitability for studied field crops. These data indicate that soils in the studied area are highly suitable for wheat, rice, maize, sugar beet, alfalfa, barley, faba bean, pea, cotton, potato, grape, and citrus. However, tomato was moderately suitable. Also, onion and pepper were marginally suitable. This may be due to the sensitivity of these crops to soil salinity, alkalinity and heavy soil texture. Figure 8 shows the percentage of land suitability for field crops, vegetables crops and fruit trees in the studied area. The suitable field crops could be arranged by preference as: sugar beet > wheat > rice > barley > maize > faba bean > cotton > alfalfa > onion. While vegetables crops arranged by preference as: pea > potato > tomato > pepper > onion. As for fruit trees were grape > citrus (Zamil *et al*. 2009).

Table 7. Final suitability of some field crops, vegetables crops and fruit trees in the studied area.

No	Crops	S1	S2	S3	S4	N1	N2
1	*Wheat*	92.88	- -	- -	- -	- -	- -
2	*Rice*	90.15	- -	- -	- -	- -	- -
3	*Maize*	88.12	- -	- -	- -	- -	- -
4	*Sugar Beet*	94.65	- -	- -	- -	- -	- -
5	*Onion*	- -	- -	- -	38.24	- -	- -
6	*Alfalfa*	83.58	- -	- -	- -	- -	- -
7	*Barley*	89.93	- -	- -	- -	- -	- -
8	*Faba Bean*	85.3	- -	- -	- -	- -	- -
9	*Pea*	82.89	- -	- -	- -	- -	- -
10	*pepper*	- -	- -	- -	39.38	- -	- -
11	*Cotton*	84.30	- -	- -	- -	- -	- -
12	*Tomato*	- -	- -	47.34	- -	- -	- -
13	*Potato*	80.55	- -	- -	- -	- -	- -
14	*Grape*	85.67	- -	- -	- -	- -	- -
15	*Citrus*	82.47	- -	- -	- -	- -	- -

Where: S1= Very suitable, S2= Suitable, S3= moderately suitable, S4= marginally suitable,
N1= currently unsuitable, and N2= permanently unsuitable.

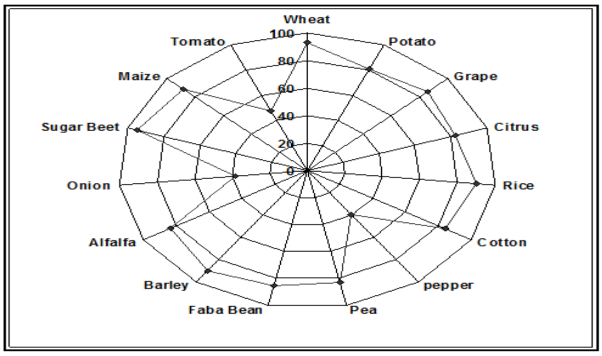

Figure 8. The percentage of land suitability for studied field crops.

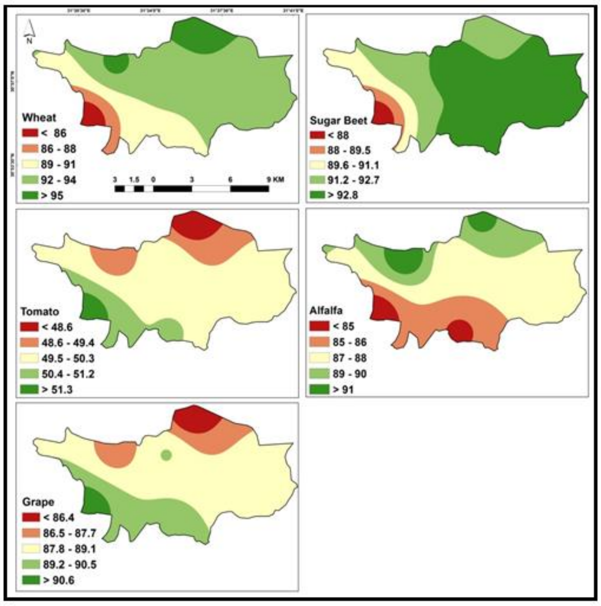

Figure 9. Land suitability for some crops in the studied area 1.

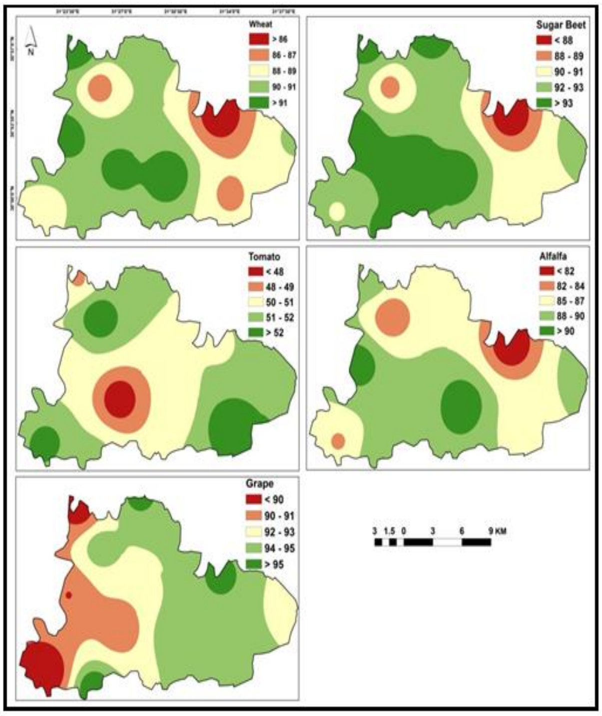

Figure 10. Land suitability for some crops in the studied area 2.

CONCLUSIONS

Land capability and suitability evaluation is enabling optimum crop development and maximum productivity. To achieve the aim of studied was using ASLE program through determining soil physical, chemical properties and fertility. Results indicate that the studied area varied from Good to Fair according to final class by ASLE model. On the other hand, land suitability for the selected field crops can be grown in these soils; where land suitability was classified into three classes: (i) S=very suitable, (ii) S3= moderately suitable and S4= marginally suitable; where the suitable crops could be arranged by preference as: sugar beet > wheat > rice > barley > maize > grape > faba bean > cotton alfalfa > pea > citrus > potato > tomato > pepper > onion. These findings provide insights, which can be used decision makers as platform for proper management practices of soil resources.

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تقييم قدرة الأرض ومدى ملاءمتها باستخدام برنامج ASLE وتقنيات GIS : دراسة حالة عن بعض اراضي شرق دلتا النيل ، محافظة الدقهلية ، مصر.

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كان الهدف من الدراسة هو تقييم قدرة الأرض ومدى ملاءمتها لبعض المحاصيل من خلال دراسة الخواص الفيزيائية والكيميائية وخصوبة بعض اراضي شرق دلتا النيل ، محافظة الدقهلية باستخدام برنامج ASLE وتقنيات نظم المعلومات الجغرافية. تم استخدام برنامج ASLE لحساب قدرة الأرض ومدى ملاءمتها لبعض المحاصيل الحقلية ومحاصيل الخضروات وأشجار الفاكهة مع ما مجموعه ١٥ محصول. لهذا الغرض ، تم توزيع ١٥ عينة من التربة بشكل عشوائي داخل المنطقة المدروسة على عمق (٠-٣٠ ، ٣٠-٦٠ و ٦٠-٩٠ سم). التي تعرضت للتحليلات الفيزيائية والكيميائية. تشير النتائج إلى أن المنطقة التي شملتها الدراسة تم تصنيفها من حيث قدرتها الانتاجية إلى فئتين : ١- C2 (جيد) و٢- C3 (متوسط). أما فيما يتعلق بملاءمة الأراضي ، فانه يمكن زراعة المحاصيل المدروسة في هذه التربة ؛ تم تصنيف مدى ملاءمة الأرض في منطقة الدراسة إلى ثلاث فئات: (١) S1 = مناسب جدًا (القمح ، الأرز ، الذرة ، بنجر السكر ، البرسيم ، الشعير ، فول الفول ، البازلاء ، القطن ، البطاطا ، العنب ، الحمضيات) ، (٢) S3 = مناسب بشكل معتدل (طماطم) و S4 = مناسب بشكل هامشي (بصل وفلفل). يمكن ترتيب المحاصيل الحقلية المناسبة حسب التفضيل على النحو التالي: بنجر السكر > القمح > الأرز > الشعير > الذرة > الفول > القطن > البصل > البصل. بينما يتم ترتيب محاصيل الخضروات حسب التفضيل على النحو التالي: البازلاء> البطاطا > الطماطم > الفلفل > البصل. أما بالنسبة لأشجار الفاكهة فكان العنب > الموالح.