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Integrating GIS and Modeling for Agricultural Land Suitability Evaluation at East Wadi El-Natrun, Egypt

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THE STUDY aimed to evaluate the capability and suitability of East Wadi El-Natrun lands, Egypt, having a total area of about 16400 feddan. The evaluation process was done using a computer program (ALES-Arid) that proposed and designed in this study. The computer program was developed basing on the minimum dataset and the mathematical modeling of different land evaluation parameters (soil physical, chemical and fertility characteristics; irrigation water quality and climate) has been utilized. ALES-Arid has been developed to facilitate the calculation of index value of land capability and land suitability, as well as their classes and limitations.

Interpolation of different soil characteristics was done to create detailed soil maps. The map of soil units was created through the overlaying process, using the interpolated maps of soil salinity, soil alkalinity, soil calcium carbonate content, along with the gravel map derived from the revised unsupervised classification. The results indicate that there are two main soil units based on gravel cover, and ten soil subunits based on soil characteristics.

The results from ALES-Arid program showed that soils of the studied area could be classified into two capability classes (C3 Fair and C4 poor). Wheat followed by olive was the most suitable crops to be grown in the studied area. The dominant limiting land capability and crop suitability factors were soil texture, available water, permeability, cation exchangeable capacity, and fertility parameters.

Voronoi polygons were building around each soil observation, and then the output data of ALES-Arid were exported to GIS environment to create land capability and suitability maps.

FAO (1976) defines land evaluation as "the assessment of land performance when used for specified purposes". The assessment includes systematic comparison of the requirements of land use with the resources offered by the land (Dent & Young 1981). In a land evaluation process, predictions are made about the expected performance of several different land uses on each land-mapping unit. These predictions should be useful for rational land-use planning by individuals, collectives, or society (FAO, 1993).

The aim of land evaluation is to provide land managers with information, which will improve the quality of land use decisions. This requires that uses be specified either broadly or in detail and the requirement for each kind of use is identified (Van de Graaff, 1988). These requirements are then compared with the characteristics and the qualities of the land units being considered.

The computer revolution led to approaches that claimed to be more quantitative. An immediate concern that was noticed with the practical application of the framework was its original bias towards soil science and a biophysical approach. Therefore some workers tried to involve agronomists to strengthen specific land use aspects and socio-economists to strengthen the economics of the land evaluation process. Marei *et al.* (1987) constructed an evaluation system named Expert System for Land Evaluation in which all calculations were carried out using a computer program based on soil characteristics and environmental conditions. El-Fayoumy(1989) utilized the same system and applied a new approach to include soil fertility properties and irrigation water quality in some scattered newly reclaimed areas of Egypt. FAO (1993) constructed an evaluation system named Land Evaluation and Farming System Analysis, abbreviated as LEFSA. Rossiter & Van Wambek (1995) suggested a simple economic land evaluation system named Automated Land Evaluation System (ALES). Ismail *et al.* (2001) suggested The Applied System for Land Evaluation (ASLE) in arid and semi-arid regions. They listed four major factors to define the land capability classification, which were: soil chemical and physical properties; environmental status; irrigation system and water qualities; and soil fertility. That approach also included land suitability classification for several crops.

Fayed (2003) used the Albero model with in MicroLEIS software (De la Rosa *et al.*, 1981) to predict the yield production for wheat and maize at El-Bostan region west Nile Delta, and found highly significant coloration between the predicted and actual yields of the two crops, since the coloration coefficients were 0.71 and 0.97, respectively. El-Bana (2003) used the same model to predict yield production for wheat and corn at Northern Nile Delta.

Coupling GIS with models

There are many strategies for coupling GIS with models. A continuum exists from loose coupling to tight coupling of the software components. Livingston & Raper (1994); Nyerges (1993); Maidment (1993) and Fedra (1993) discussed the types of coupling that could be sought between environmental models and GIS. Loose coupling of GIS and models involves the use of a GIS for the task for which it is best suited: generation and organization of input data as well as display of output data (Fig. 1). In this strategy, output from the GIS is organized as input to the model and output from the model is subsequently submitted to the GIS for display using a common binary file format (Goodchild *et al.*, 1992). A simple interface program is used to convert the files from one format to another.

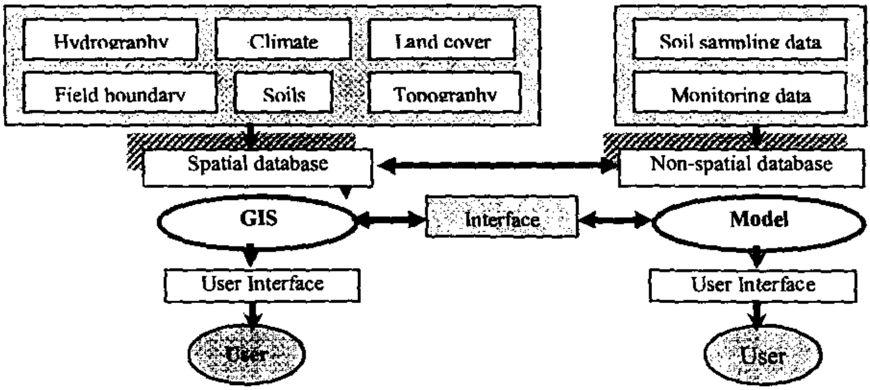


Fig. 1. Schematics for loose coupling of model and GIS.

Minimum dataset (MDS) is the smallest number of attributes that describe a system, without distorting the facts about its reality. Scientists today have increased data gathering capabilities due to new instrumentation and storage capabilities. As a result, the fields of soil and water sciences, like many experimental sciences, are data rich. This richness challenges us to organize data and ancillary information in ways that make them readily and meaningfully accessible. The concept of minimum dataset depends on several factors such as minimizing interpretation difficulties, achieving flexibility and facilitating synthesis of information (Baker *et al.*, 2000). There is no consensus on what a MDS should contain (Larson & Pierce, 1994).

A relational database, simply defined, is a database that is made up of tables and columns that relate to one another. These relationships are based on a key value that is contained in a column. The relational database model was developed in the early 1970s. It consists of data stored in columns and tables that could be related to each other. A relational database is very intuitive, it mimics the way people think. People tend to group similar objects together and break down complex objects into simpler ones, so relational databases are true to this nature and most modern databases use a relational model to accomplish their tasks (Maslakowski, 2000).

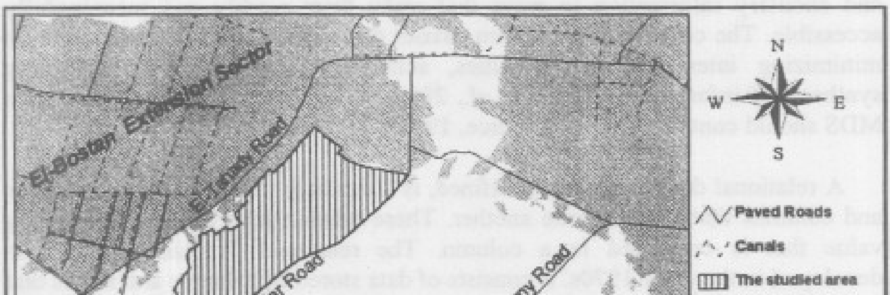
A computer as a machine cannot understand any person's spoken language; therefore, user must be adapted to the machine and learn a language that the computer can understand. That shared language written using specified pattern called "program". A program is a set of arranged instructions that make the computer do something, "The term program is often used synonymously with application" .

Geographic information System (GIS) and Modeling are advanced technologies and concepts that are widely available for data handling, processing and management. The integration of GIS and Modeling could provide a powerful means for analyzing and synthesizing information about land resources, and to provide land managers with information which will improve the quality of land use decisions (Olsson, 1989 and Amarsaikhan & Ganzorig, 1995).

The aims of the present study are: i) Assess the soil physical, chemical, and nutritional characteristics; ii) Integrate GIS and modeling to create and utilize the detailed soil maps and to estimate the capability and suitability of east Wadi El-Natrun lands for different uses through designing land evaluation computer software, based on the minimum dataset; and construct its linked database package.

The study area

The study area lies to the west of Nile Delta, and located at about 110 km south Alexandria on the eastern side of Alexandria-Cairo desert road. It is bounded by UTM coordinates 824799 - 839141 E and 3369453 - 3382300 N, in UTM zone 36. The study site occupies about 16446 feddans (6907 hectare) as illustrated in Map 1. The investigated area is accessible mainly through Alexandria-Cairo desert road, as well as El-Mattar and El-Tahady roads.



Map 1. Location map of the studied area.

The climate of the study area is characterized by hot dry summer and warm winter; the climatic data were collected from Wadi El-Natrun meteorological station, and represent the average for the period from 1960 to 2000. Generally, the summer average temperature value was 25.63 ° while in the winter was 17.30°. The maximum rainfall value was 10.5 mm/year that recorded at December, while the minimum value was zero in June, July and August.

The old alluvial plain is the geomorphological unit that represents the study area. Its surface is a rolling plain sloping to the north and northeast, slightly undulated and essentially covered with sand sheets and low sand belts in its northern part, coarse sand and old gravels together with fossil wood in its southern part. The ground elevation of this plain varies between 60 m (A.S.L) near Sadat City and 20m (A.S.L) near the Nile Delta, with a general slope to the north (Shata,1962; El Fayoumy,1964 and Attia, 1975).

The Pleistocene and recent deposits of Holocene which located East of Wadi El-Natrun and to the west of the Nile Delta. These sediments have widely distribution in the studied area and are essentially developed into gravel and sand faces. On the other hand, the Pliocene sediments are distributed on the studied area and developed into marine and fresh water faces. It developed into a lower portion composed of green sandy clays and an upper one built up by calcareous grits (Shata *et al.*,1970).

Material and Methods

Soil and water sampling and laboratory analyses

The field work had done in summer, 2002 and twenty five representative soil profiles georeferenced using GPS and dug. Thirty seven soil augers were sampled. Three irrigation water samples were collected from different artesian wells. Laboratory analysis was carried out and included soil physical, chemical, and nutritional analysis and irrigation water analysis.

Data handling and pre-processing

Four topographic maps (scale 1:50000) which represent the studied area were obtained and their geographic coordinates were transformed into Universal Transverse Mercator (UTM) system, then digitized using Terrasoft GIS software (Digital Resource Systems, 1991),and they preprocessed through edge matching, merging, and data format conversion. The digitized contour lines and spot heights were exported to Arc View software 3.2 as vector format, and the contour gridder extension was utilized to generate the Digital Elevation Model (DEM).

Interpolation of different soil characteristics (EC, $CaCO_3$, and ESP) was done to create detailed soil maps. The map of soil units were created by Arc view-GIS 3.2 through the overlaying process, using the interpolated maps of soil salinity, soil alkalinity, soil calcium carbonate content, along with the gravel map derived from the revised unsupervised classification. Voronoi polygons were building around each soil observation, and LINKED with soil capability and suitability databases to map different crop suitability classes.

Agriculture land Evaluation System for arid region (ALES-Arid) as a new approach for land capability and suitability evaluation. It was designed using MS-VB programming language based on the minimum dataset concept and its database was constructed using MS-access. The land evaluation parameters used in the model were soil physical, chemical and fertility characteristics; irrigation water quality and climatic data.

ALES-Arid is linked directly with integrated databases and coupled indirectly (loose coupling) with GIS. Through ALES-Arid program, land evaluation algorithms are expressed in notation forms that can be understood by a calculating device. Optimization tools based on land evaluation models are considered very important to formulate decision alternatives. According to Storie (1964); six productivity classes were identified as shown in Table 1.

TABLE 1. Productivity classes and ratings according to Storie (1964).

Class	Description	Rating (%)
C_1	Excellent	80-100
C_2	Good	60-80
C_3	Fair	40-60
C_4	Poor	20-40
C_5	Very poor	10-20
C_6	Non- agriculture	<10

Using Visual basic version 6.0, a mathematical model was constructed for calculating the following indices and limitations:

a. Land capability index and limitations.

b. Land suitability index and limitations for 28 crops, and

c. Predicted yield for wheat and corn.

The program has been built up throughout the following steps:

Step 1: The program initiated by general remarks for whole used variables and symbols to be identified through different processing stages (Diminution statements).

Step 2: The structured data stored in linked relational database are retrieved and temporally stored.

Step 3: The stored data have to be transformed into average weight for each observation (profiles and augers) according to the following:

a) For each observation, the number and thickness of each layer (horizon) are determined, in addition to total soil depth.

b) The average weighted value for each observation belongs to each parameter (soil property) is calculated based on the parameter value, horizon thickness, and horizon sequence according to the following equation:

$$V = \left[\frac{\sum_{i=1}^{n} (vi * ti)}{T} \right]$$

Where:
V is the average weight value of the property within the observation, *v* is the property value, *t* is the horizon thickness, *i* is the horizon sequence, and *T* is the total soil depth.

Step 4: Based on the matching between weighted average values of soil parameters and suggested ratings within the program, a capability index and limitation of each parameter is estimated as a percentage. Limiting parameter for land capability are those in which index value less than 50 %.

For each group, the inner variable indices (*I*) are multiplied to calculate the final index (I_g) according to the following equations:

$$Log(Ig) = \frac{\log(I1 * I2 * .... * In)}{n} = M$$

$$Ig = Anti\log(M) = (10)^{M}$$

After the program estimates the capability index of each group, it determines the capability classes according to capability categories suggested by Storie (1964) and capability limitations according to the index value of each parameter.

Step 5: Land suitability indices and limitations for 28 crops are calculated according to matching between the standard requirements of these crops (internal coded data within the program) and various soil parameter levels.

Step 6: The land suitability class is identified by assigning each land suitability index to confined category as shown in Table 2.

TABLE 2. Land suitability classes, definition and ranges (FAO, 1979 and Ismail *et al.*, 1994a & 2001) .

Class	Class definition	Range %
S1	Highly suitable	100- 80
S2	Moderately suitable	80-60
S3	Marginally suitable	60-40
S4	Conditionally suitable	40-20
NS1	Potentially suitable	20-10
NS2	Actually unsuitable	<10

Step 7: The program calculates predicted yield for wheat and corn according to the following polynomial equations suggested by De la Rosa *et al.* (1981), taking into account the main effects of the variables X and the second order interactions.

$$Y_1 = -1740.3 + 52.1\ X_1 + 33.0\ X_3 + 27.2\ X_4 + 238.0\ X_5 - 0.4\ X_1X_3 - 6.2\ X_5X_7 + 11.0\ X_6X_7$$

$$Y_2 = 1085.4 + 30.0\ X_1 + 28.0\ X_3 - 418.1\ X_6 + 17.0\ X_2X_5 + 0.2\ X_2X_7 - 39.2\ X_5X_7 + 21.0\ X_6X_7$$

Where: Y1 = productivity of wheat (kg/ha); Y2 = productivity of corn (kg/ha); X1 = useful depth (cm); X2 = clay content (%); X3 = depth to hydromorphic features (cm); X4 = carbonate content (%); X5 = salinity (dS/m); X6 = sodium saturation and X7 = cation exchange capacity (meq/100 gm soil).

Step 8: The land capability indices, classes, and limitations, as well as suitability indices, classes, and limitations for field crops, fruit trees, vegetables and forage crops, along with predicted yield for wheat and corn are exported as MS-Access database, to be presented using ALES-Arid interface program. GIS software can read the output from ALES-Arid database as DBF format for visualization of land capability and suitability maps. This is considered as loose coupling between ALES-Arid software and Arc View GIS software. The flowchart for data processing is illustrated in Fig. 2.

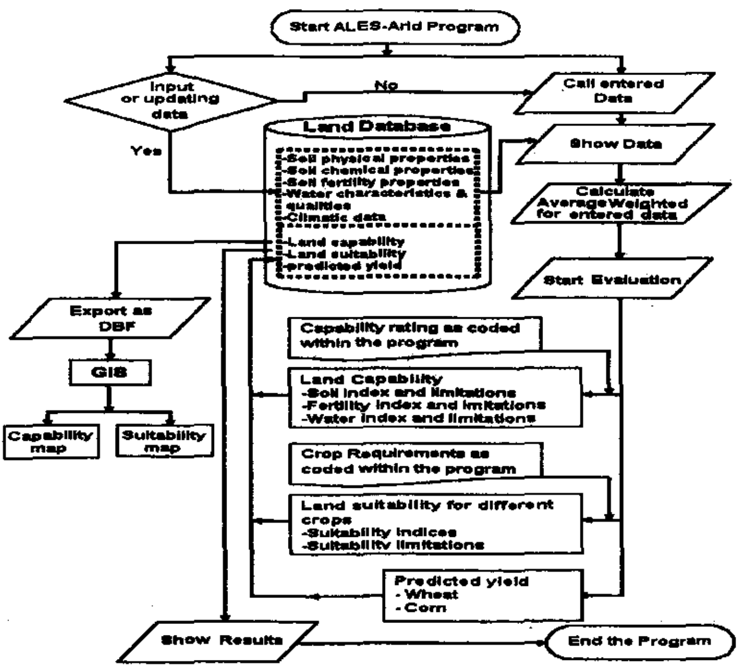
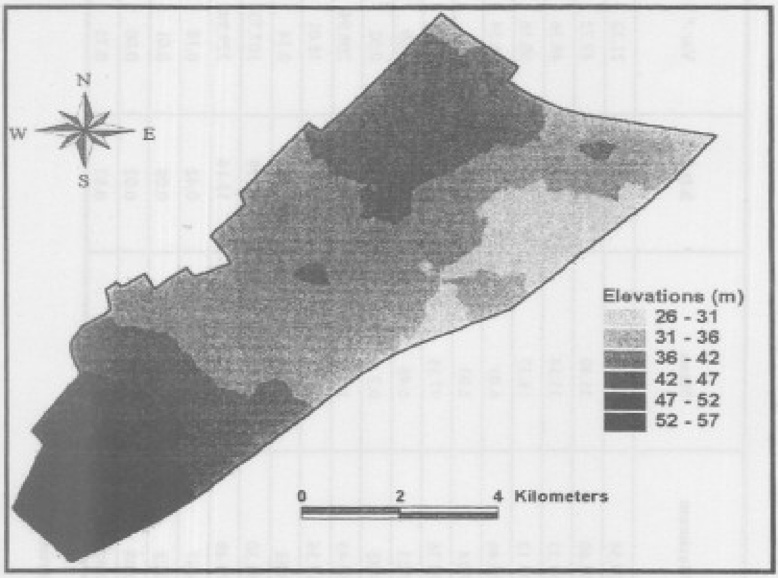


Fig. 2. The flowchart of the agriculture land evaluation system for arid region (ALES-Arid).

Results and Discussions

The digital elevation model (DEM) is illustrated in Map 2, and shows that elevations ranged from 26 m A.S.L. to 57 m A.S.L. The analysis of digital elevation model indicated that the elevation of the studied area decrease towards the northeastern part of the studied area.



Map 2. Digital elevation model of the studied area.

Soil Characterization

The examination of data resulted from laboratory analysis, and statistical analysis as shown in Table 3 indicated that:

According to grain size analysis, soil texture is generally coarse with very low percentage of clay and silt contents. Sand percentage ranged between 92.26 % and 98.36 %, which means that the dominant class of soil texture is sandy (Table 3).

The gravels percent (more than 2 mm in diameter) varies in wide range in the study area (among and within the studied soil profiles) between 3.32 % and 69.43 %.

The available water was very low and ranged between 6.04 % and 7.33 %. This is expected due to the relatively low clay content, and consequently low water holding capacity.

TABLE 3. Statistical parameters of soil physical, chemical and fertility properties.

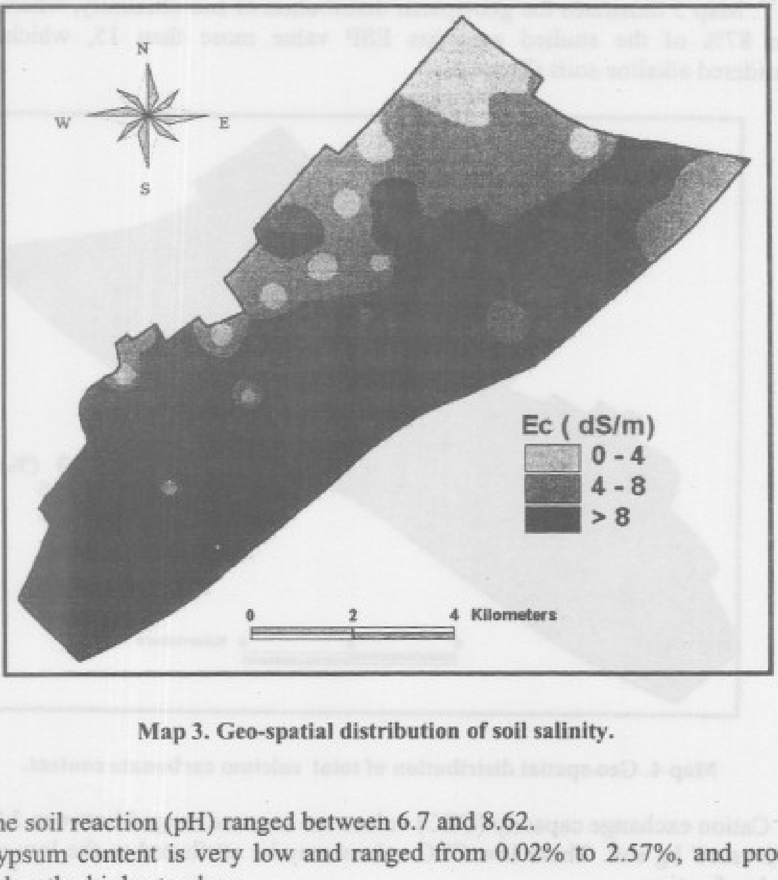
St. parameters / Properties	Minimum	Maximum	Mean	S.D.*	Var.*	C.V.%*
Very coarse sand %	5.15	29.58	13.92	4.62	21.32	33.18
Coarse sand %	9.75	52.60	25.49	6.91	47.72	27.10
Medium sand %	19.82	55.33	33.54	6.81	46.36	20.30
Fine sand %	6.26	33.12	18.37	7.10	50.36	38.62
Very fine sand %	1.19	26.46	6.03	4.07	16.54	67.44
(Silt + Clay) %	0.83	7.24	2.03	1.10	1.21	54.18
Sand %	92.26	98.36	97.35	1.08	1.17	1.11
Available water %	6.04	7.33	6.46	0.31	0.09	4.76
Soil hyd. Cond.(m/hr)	0.1	0.85	0.2	0.13	0.02	64.74
Gravel %	3.32	69.43	18.30	14.39	206.94	78.61
CaCO3 %	0.07	17.36	4.31	4.24	18.01	98.38
pH	6.70	8.62	7.60	0.38	0.14	4.98
EC (dS/m)	0.84	50.30	13.04	10.38	107.73	79.57
ESP	6.10	79.49	29.61	15.16	229.94	51.21
Gypsum %	0.02	2.57	0.35	0.42	0.18	119.97
OM %	0.01	0.28	0.14	0.08	0.01	54.44
P (ppm)	0.01	0.08	0.03	0.02	0.00	49.60
CEC (cmol/ kg soil)	3.88	7.93	4.68	0.87	0.75	18.51

*S.D.=Stander deviation, Var=Variance, C.V.=Coefficient of variance

Soil hydraulic conductivity has high values ranging between 0.10 and 0.85 m/hr. Field observations showed that soil depth is generally deep to very deep, as it reached more than 150 cm.

The main soil chemical characteristics were analyzed and the examination of statistical analysis data summarized in Table 3 indicated that:

Soil salinity varies in wide range among the studied soil profiles and within some profiles, and ranged between 0.84 and 50.3 dS/m, which means that the soils are none saline to very saline. Profiles no. (11, 17, 18, 23, and 25) were considered non saline, as their EC values ranged from 0.84 to 3.64 dS/m. The dominant ions were Na^+ and Cl^-, followed by Ca^{++} and Mg^{++}. The geo-spatial distribution of soil salinity is shown in Map 3. It indicated that the soil salinity in the southeastern part of the study area is higher than the northwestern part. Table 4 shows the acreages and percentages of different salinity classes.



Map 3. Geo-spatial distribution of soil salinity.

The soil reaction (pH) ranged between 6.7 and 8.62.

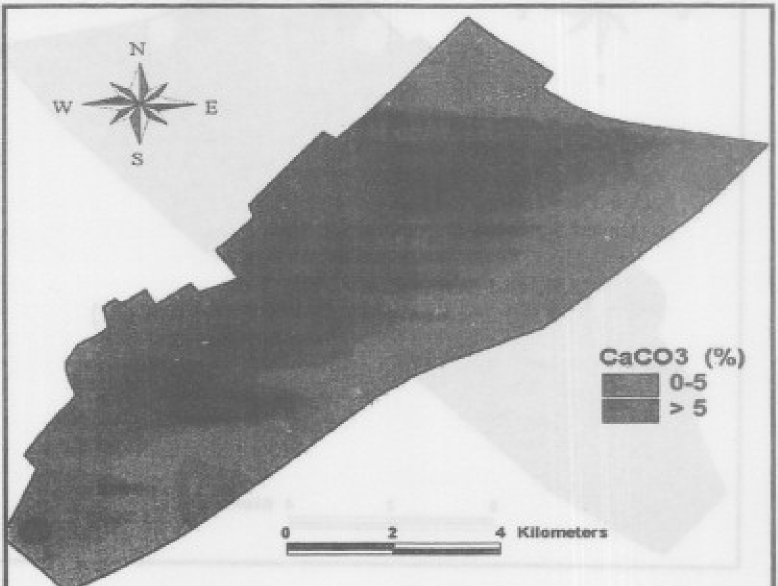
Gypsum content is very low and ranged from 0.02% to 2.57%, and profile No. 5 has the highest values.

TABLE 4. Areas and percentages of salinity

EC dS/m	Area %	Area (Fed.)
0-4	5.48	901.27
4-8	22.18	3647.8
> 8	72.34	11897.39

There are moderately variations in total calcium carbonate content, as it varies between 0.07% and 17.36 %. Large part of the studied area is considered non- calcareous as shown in Map 4. Table 5 shows the percent of $CaCO_3$ distribution.

The Exchangeable sodium percentage (ESP) has strong variations, as it ranged from 6.10 to 79.49, depending upon the concentration of Na^+ and Ca^{++}, Mg^{++}. Map 5 illustrates the geo-spatial distribution of soil alkalinity, where more than 87% of the studied area has ESP value more than 15, which were considered alkaline soils (Table 6).

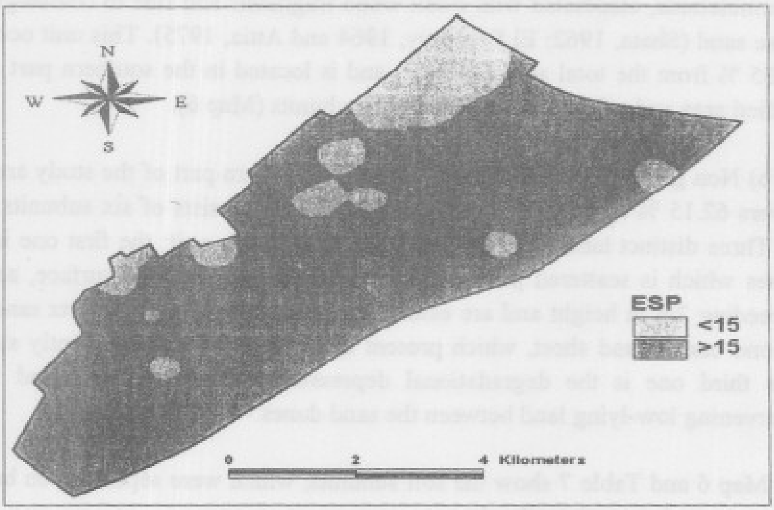


Map 4. Geo-spatial distribution of total calcium carbonate content.

Cation exchange capacity (CEC) values are low and ranged between 3.88 and 7.93 cmol/ kg soil. These low CEC values may be attributed to the low content of clay fraction.

TABLE 5. Areas and percentages of calcium carbonate content.

$CaCO_3$ %	Area %	Area (Fed.)
< 5	63.47	10438.57
> 5	36.53	6007.89



Map 5. Geo-spatial distribution of soil alkalinity.

TABLE 6. Alkalinity classes and their areas and percentages.

Range	Area %	Area (Fed.)
< 15	12.34	2029.50
>15	87.66	14416.96

The studied area is totally poor in fertility as no fertilizers were applied because the area is non-cultivated soils. Table 3 shows the statistical analysis of organic mater content (OM %), available phosphorus (P, ppm). It clears that (OM %) is very low as the maximum value reaches 0.28 %, and available phosphorus is generally low and varies between 0.01 and 0.08 ppm. Available nitrogen is very low and takes value zero ppm.

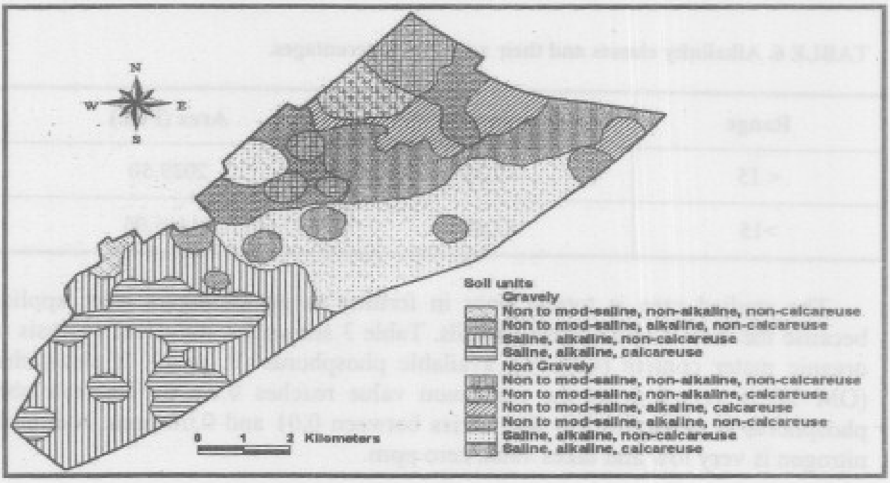
Soil mapping units

There are two main soil texture units based on gravel cover, namely, gravely and none gravely as shown in Map 6. The following is a brief description of these units:

a) Gravely: the surface of this unit represent a typical example of pavement plain, its surface is covered with shirts, flinty, gravelly deposits, and sand accumulations, associated with fossil wood fragments and fine to coarse-grained loose sand (Shata, 1962; El Fayoumy, 1964 and Attia, 1975). This unit occupied 37.85 % from the total area (Table 7) and is located in the southern part of the studied area and subdivided into four soil subunits (Map 6).

b) Non gravely: this unit is located in the northern part of the study area and covers 62.15 % from the total area (Table 7) and consists of six subunits (Map 6). Three distinct landforms can be recognized in this unit: the first one is sand dunes which is scattered patches covering about 20 % of the surface, and not exceeding 2m in height and are essentially composed of loose quartz sand. The second one is sand sheet, which present in the form of flat and gently sloping. The third one is the degradational depressions, which are restricted to the intervening low-lying land between the sand dunes.

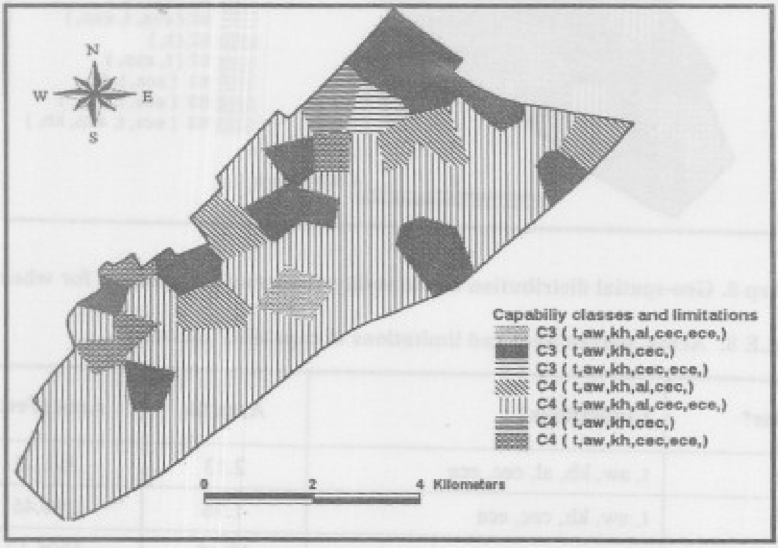
Map 6 and Table 7 show the soil subunits, which were separated on basis of the two previous main soil units.



Map 6. Soil mapping units of the studied area.

TABLE 7. The soil units description and areas in the studied area.

Soil Units		Area %	Area (Fed.)
Non gravelly	Non to moderately saline, non alkaline, non calcareous.	6.02	990.07
	Non to moderately saline, non alkaline, calcareous.	3.11	511.49
	Non to moderately saline, alkaline, calcareous.	6.88	1131.52
	Saline, alkaline, calcareous.	13.58	2233.43
	Saline, alkaline, non calcareous.	22.94	3772.81
	Non to moderately saline, alkaline, non calcareous.	9.62	1582.15
Gravelly	Non to moderately saline, alkaline, non calcareous.	1.08	177.63
	Saline, alkaline, calcareous.	12.70	2088.70
	Non to moderately Saline, non alkaline, non calcareous.	0.89	146.37
	Saline, alkaline, non calcareous.	23.18	3812.29



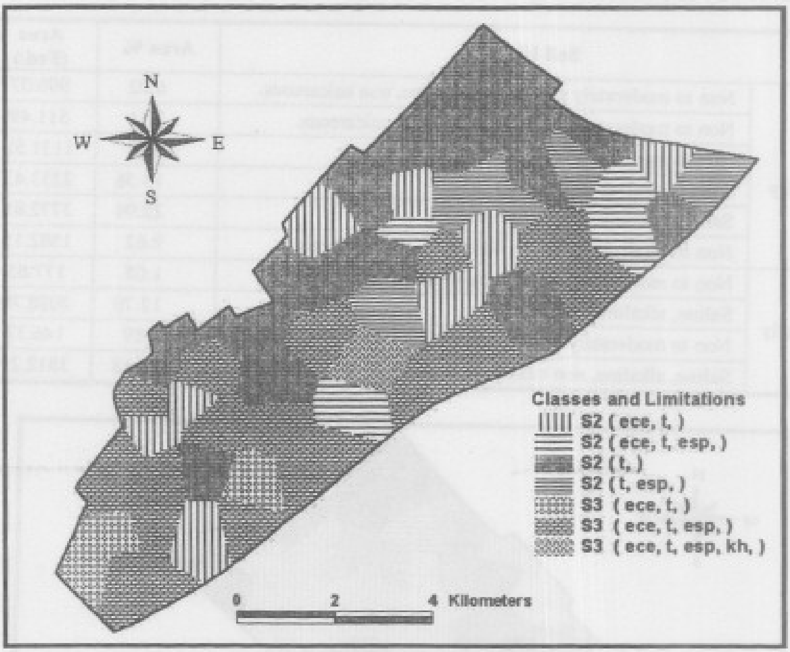
Map 7. Geo-spatial distribution of capability classes and limitations.

Land evaluation using proposed Ales-Arid Software

The Agriculture Land Evaluation System for arid region (ALES-Arid) is used to define the land capability and suitability and yield prediction as follows:

A) Land capability evaluation

Map (8) shows the spatial distribution of the capability classes. Fair land capability class (C3) occupied about 23.39 % from the total acreage (Table 8), where the limiting parameters were soil texture, available water, permeability, alkalinity, cation exchangeable capacity and salinity.



Map 8. Geo-spatial distribution of suitability classes and limitations for wheat.

TABLE 8. Areas, percentages and limitations of capability classes.

Class*	Limitations*	Area %	Area (Fed.)
C3	t, aw, kh, al, cec, ece	2.13	351.25
C3	t, aw, kh, cec, ece	1.76	290.46
C3	t, aw, kh, cec	19.49	3205.12
C4	t, aw, kh, al, cec, ece	60.13	9886.23
C4	t, aw, kh, cec, ece	3.91	642.81
C4	t, aw, kh, al, cec	9.46	1555.68
C4	t, aw, kh, cec	2.16	356.33

*C1=Excellent, C2=good, C3=fair, C4=poor, C5=very poor,C6=non-agriculture
**t=soil texture, aw=available water, kh=soil hydraulic conductivity, al=alkalinity, cec=cation exchange capacity, ece=soil salinity, om=organic mater, n=nitrogen, p=phosphorous, k= potassium, cl= chloride.

B) Land suitability evaluation

Different land suitability classes and indices for several crops were predicted based on the matching between land qualities and characteristics and crop standard requirements using ALES-Arid program. The land suitability for twenty-eighth crops (field crops, vegetables, forage crops and fruit trees) were investigated.

Generally, data of land suitability classes and limitations, which resulted from the application of ALES-Arid program indicated that 60.4% of the total studied area is moderately suitable (S2) for wheat (Table 9), 68.48 % is conditionally suitable (S4) for maize (Table 10), and 71.07 % is conditionally suitable (S4) for peanut (Table 11). The geo-spatial distribution of field crops suitability is represented in maps 8, 9 and 10, respectively, which indicate that the main suitability limitations in the studied area are soil salinity, soil texture, ESP, and permeability. The geo-spatial distribution of land suitability classes in the study area for potato (Map 11) showed that more than 67% of the area (Table 12) is classified as conditionally suitable land (S4). The geo-spatial distribution of land suitability in the studied area for olive (Map 12) showed that more than 45% of the area (Table 13) is classified as marginally suitable land (class 3), while more than 50% of the area (Table 14) is classified as conditionally suitable (class 4) for citrus (Map 13).

TABLE 9.The final land suitability classes and limitations for wheat.

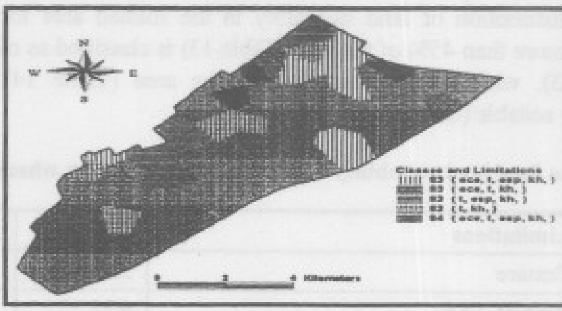
Class	Limitations	Area %	Area (Fed.)
S2	Texture	32.69	5374.40
S2	Texture, ESP	9.12	1499.80
S2	EC, texture	11.85	1948.88
S2	EC, texture, ESP	6.74	1107.41
S3	EC, texture	4.56	748.88
S3	EC, texture, ESP	32.90	5409.36
S3	EC, texture, ESP, permeability	2.14	351.25

TABLE 10. The final land suitability classes and limitations for the maize.

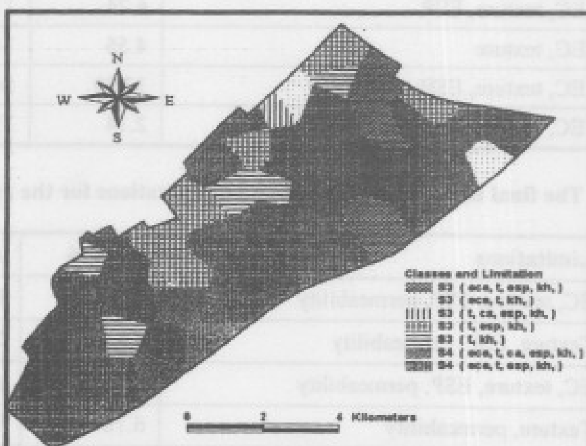
Class	Limitations	Area %	Area (Fed.)
S4	EC, texture, ESP, permeability	68.48	11257.58
S3	Texture, ESP, permeability	12.33	2027.72
S3	EC, texture, ESP, permeability	10.32	1696.23
S3	Texture, permeability	6.18	1015.32
S3	EC, texture, permeability	2.70	443.13

TABLE 11. The final land suitability classes and limitations for peanut.

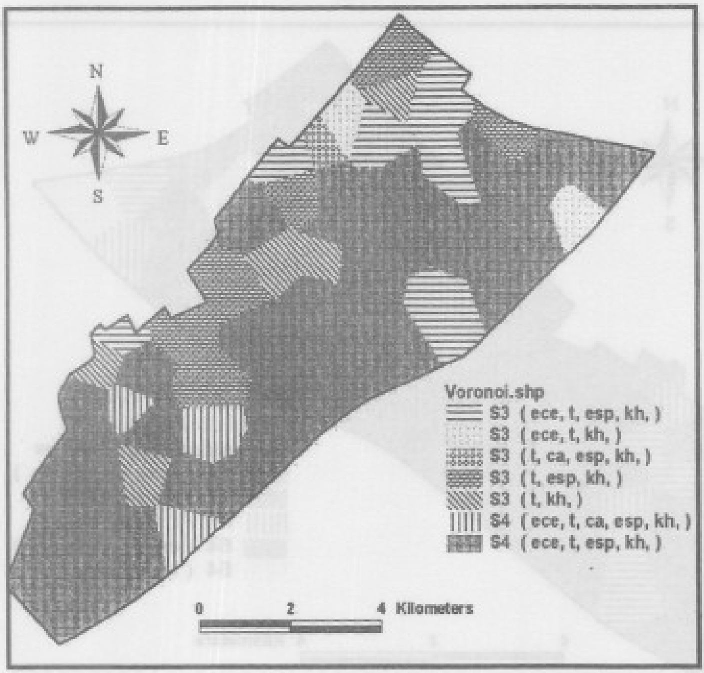
Class	Limitations	Area %	Area (Fed.)
S3	EC, texture, ESP, permeability	7.72	1269.2
S3	EC, texture, permeability	2.70	443.1
S3	Texture, CaCO3, ESP, permeability	0.90	147.6
S3	Texture, ESP, permeability	11.43	1880.1
S3	Texture, permeability	6.18	1015.3
S4	Texture, permeability	4.54	747.2
S4	EC, texture, ESP, permeability	66.53	10937.5



Map 9.Geo-spatial distribution of suitability classes and limitations for maize.



Map 10. Geo-spatial distribution of suitability classes and limitations for peanut.



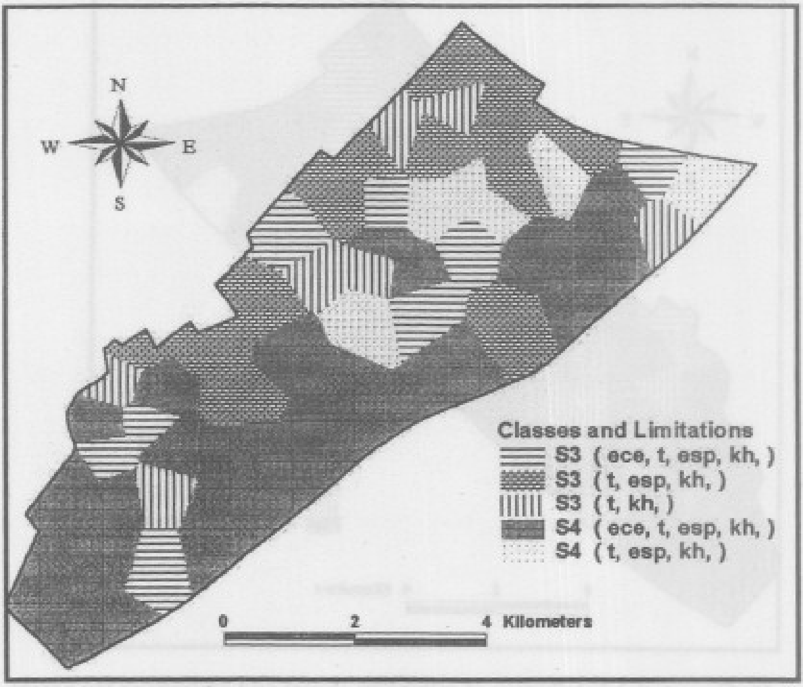
Map 11. Geo-spatial distribution of suitability classes and limitations for potato.

TABLE 12. The final land suitability classes and limitations for potato.

Class	Limitations	Area %	Area (Fed.)
S3	Texture, ESP, permeability	11.44	1880.12
S3	Texture, $CaCO_3$, ESP, permeability	0.90	147.60
S3	EC, texture, ESP, permeability	11.49	1888.23
S3	Texture, permeability	6.18	1015.32
S4	EC, texture, ESP, permeability	62.76	10318.39
S4	EC, texture, $CaCO_3$, ESP, permeability	4.54	747.19

TABLE 13.The final land suitability classes and limitations for olive.

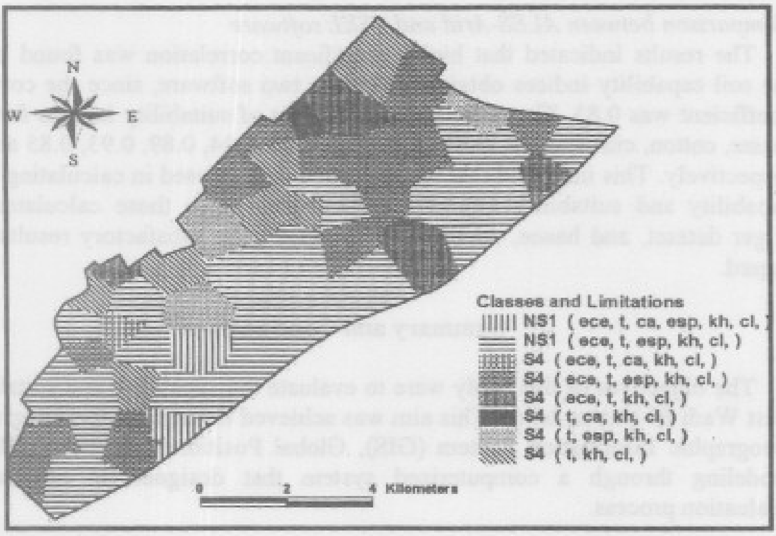
Class	Limitations	Area %	Area (Fed.)
S3	EC, texture, ESP, permeability	12.79	2101.95
S3	Texture, permeability	8.87	1458.45
S3	Texture, ESP, permeability	23.82	3915.95
S4	EC, texture, ESP, permeability	45.40	7463.82
S4	Texture, ESP, permeability	9.12	1499.80



Map 12. Geo-spatial distribution of suitability classes and limitations for olive.

TABLE 14. The final land suitability classes and limitations for citrus.

Class	Limitations	Area %	Area (Fed.)
S4	EC, texture, ESP, permeability, chloride	23.48	3861.40
S4	Texture, ESP, permeability, chloride	5.98	984.44
S4	Texture, permeability, chloride	11.62	1910.99
S4	Texture, permeability, $CaCO_3$, chloride	0.89	147.60
S4	EC, texture, permeability, chloride	8.62	1417.65
S4	EC, texture, $CaCO_3$, permeability, chloride	0.93	153.07
NS1	EC, texture, ESP, permeability, chloride	44.83	7370.69
NS1	EC, texture, $CaCO_3$, ESP, permeability, chloride	3.61	594.11



Map 13.Geo-spatial distribution of suitability classes and limitations for citrus at East Wadi El-Natrun area.

C) Crop yield prediction

ALES-Arid software allow prediction for crop yield for two crops (wheat and corn) based on limited number of soil properties, these are useful depth, clay content, depth to hydromorphic features, carbonate content, soil salinity, exchangeable sodium percentage (ESP) and cation exchange capacity (CEC).

Predicted crop yield is shown in Table 15. Regarding wheat yield, the data indicated that the soil salinity and alkalinity properties were out of range in all investigated soil profiles, except profiles No (18 and 25) which have EC and ESP values within range. On the other hand, the clay content was out of range for determining the predicted yield of corn. Identical numbers were resulted from the application of Albero model in MicroLEIS software Table 15.

TABLE 15. The predicted yield of wheat (kg/ha and Ardab/fed) in the studied area.

Profiles No	Predicted yield for wheat	
	kg/ha	Ardab/fed
18	3819.18	10.69
25	3883.44	10.87

Comparison between ALES-Arid and ASEL software

The results indicated that highly significant correlation was found between the soil capability indices obtained from the two software, since the correlation coefficient was 0.83. The correlation coefficient of suitability indices for wheat, maize, cotton, citrus, olive, and potato were 0.91, 0.94, 0.89, 0.93, 0.85 and 0.97, respectively. This indicated that the minimum dataset used in calculating the soil capability and suitability indices were comparable to those calculated using larger dataset, and hence, ALES-Arid software gave satisfactory results in this regard.

Summary and Conclusion

The objectives of this study were to evaluate the capability and suitability of East Wadi El-Natrun lands. This aim was achieved throughout the integration of Geographic Information System (GIS), Global Positioning System (GPS) and modeling through a computerized system that designed to automate the evaluation process.

The digital elevation model (DEM) indicated that the elevations of the studied area decrease gradually from 57 m A.S.L at the south part to 26 m A.S.L towards the north eastern part.

The studied soil samples are characterized by sandy texture, high variability of soil salinity, sodicity, and gravel content. It is poor in fertility as the area is non-cultivated and cation exchange capacity (CEC) values were low.

The results of ALES-Arid program indicated that the soils of the studied area could be classified into two capability classes (C3 Fair and C4 poor), wheat followed by olive were the most suitable crops to be grown in the studied area. The general dominant limiting land capability and crop suitability factors were soil texture, available water, permeability, cation exchangeable capacity, and fertility parameters. The predicted yield indicated that the soil salinity and alkalinity are the limiting parameters for producing wheat, except profiles No (18 and 25), which have EC and ESP values within model range. On the other hand, the clay content is the limiting parameter for predicting the yield of corn in the whole investigated area. Comparing the results obtained from ALES-Arid software with those obtained from ASLE software showed high correlation, which means that the minimum dataset used in this study is satisfactory.

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تكامل نظم المعلومات الجغرافية والنمذجة لتقييم صلاحية الأرض للزراعة بمنطقة شرق وادى النطرون– مصر

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يهدف هذا البحث إلى تقييم قدرة الأرض الانتاجية ومدى صلاحيتها للزراعة بالمحاصيل المختلفة بمنطقة شرق وادى النطرون، قطاع غرب الدلتا، مصر وتقع منطقة الدراسة على بعد ١١٠ كم جنوب مدينة الاسكندرية، شرق الطريق الصحراوى الاسكندرية– القاهرة، وتبلغ مساحتها حوالى ١٦٤٤٦ فدان.

تم تحقيق الأهداف المرجوة من البحث من خلال التكامل بين نظم المعلومات الجغرافية ونظام تحديد المواقع(GPS). بالاضافة الى تصميم برنامج مقترح (ALES-Arid) لتقييم أراضى منطقة الدراسة بحيث يعتمد على الخواص الفيزيائية والكيميائية للتربة، خصوبة التربة ، جودة مياة الرى، وكذلك البيانات المناخية، والبرنامج يعتمد أيضاً على استخدام مفهوم الحد الأدنى من البيانات Minimum Dataset، وتم انشاء قاعدة البيانات الخاصة بمنطقة الدراسة والتى ترتبط مباشرة ببرنامج التقييم المقترح.

أظهرت النتائج أن أراضى منطقة الدراسة تشتمل على عشر تحت وحدات أرضية نتجت من عملية الربط والتوقيع Overlaying process باستخدام برنامج ArcView 3.2 وذلك لخرائط التربة التالية : خريطة توزيع الملوحة وخريطة توزيع الكربونات الكلية وخريطة توزيع نسبة الصوديوم المتبادل (ESP) وخريطة توزيع نسبة الحصى على سطح الأرض.

نتائج برنامج التقييم ALES-Arid المصمم والمستخدم فى هذه الدراسة أظهرت أن أراضى منطقة الدراسة تتبع درجتين انتاجيتين هما (C3 -fair) ، (C4-poor) ، وأن أنسب المحاصيل للزراعة فى المنطقة هما محصولى القمح يليه الزيتون. بينما وجد أن العوامل السائدة والمحددة لقدرة الأرض الانتاجية بمنطقة الدراسة وكذلك مدى ملائمتها للزراعة بالمحاصيل المختلفة هى قوام الأرض ونسبة الماء المتاح ونفاذية التربة والسعة التبادلية الكاتيونية وخصوبة التربة. كان هناك معاملات ارتباط عالية عند مقارنة النتائج المتحصل عليها من برنامج ALES-Arid مع تلك المتحصل عليها من برنامج ASLE ، وهذا يدل على أن استخدام مفهوم minimum dataset خلال عملية التقيم قد أعطى نتائج مرضية، وهذا يستدعى تفضيل استخدام برنامج ALES-Arid توفيراً للوقت والمجهود والمال فى الدراسة.