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Land Capability Assessment by Using Geographic Information System in North Delta, Egypt

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THE PROBLEMS of ever-increasing population and increased competition for a variety of stresses, especially in the Nile Delta, Egypt, have induced tremendous pressure on shrinking land resources. Agricultural land in Egypt is limited, so we need to identify and preserve it for agricultural use. This study aims to produce the thematic maps of soil properties assess the land capability by using the Geographic Information System (GIS). To realize this objective, the fieldwork laboratory analysis and satellite data (Landsat ETM+ and ASTER images) were used in a Geographic Information System to outline the landforms and land capability of the studied area. A representative soil samples were collected according to landforms, South Burullus Lake, North of the Nile Delta, Egypt.

Soil taxonomic units were defined as Aquallic Salorthids, Typic Haplosalids, Typic Torrifluvents and Vertic Torrifluvents. Their corresponding area percent were 31.97, 13.48, 1.25 and 53.3 % of the total area, respectively. The dominant main Land forms were flood plain and lacustrine plain (74.7, 25.3 % of the total area).

The thematic layers for $CaCO_3$ and clay content, water table (WT) depth, EC, pH, SAR, OM, and Bulk density (Bd) were created in ArcGIS 10.1 using the Inverse Distance Weighting (IDW) method. These layers were matched together to assess the land capability classes. The obtained land capability classes are I, II, III and IV comprised 6.30, 28.95, 60.57 and 4.18% of the total study area, respectively.

Keywords: Soil capability, Spatial analyses, Soil mapping, Remote sensing and GIS.

Land capability classification is a system of grouping soils, mostly on the basis of their capability to create common cultivated crops without deteriorating over a long period of time.

In recent years thematic mapping has undergone a revolution as the result of advances in geographic information science and remote sensing. For soil

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mapping archived data are often sufficient and it’s available at low cost. Integration of remote sensing within a GIS database can decrease the cost, reduce the time and increase the detailed information gathered for soil survey (Green, 1992). Particularly, the use of Digital Elevation Model (DEM) is important to derive landscape attributes that are utilized in the landforms characterization (Brough, 1986 and Dobos, *et al.*, 2000).

Land capability is viewed as the inherent capacity of land to perform at a given level for a general use. Other peoples see capability as a classification of land primarily in relation to degradation hazards, whilst some regard the term “suitability” and “capability” as interchangeable (FAO, 1976).

Land capability refers to the potential of the land to sustain a number of predefined land uses in a built-in descending sequence of desirability: arable crops, pasture, woodland, recreation/wildlife (Mohamed, 2002).

The spatial analysis is defined as the analytical techniques associated with the study of locations of geographic phenomena together with their spatial dimensions and their associated attributes (ESRI, 2001). The use of this technique in evaluating the soil capability, allow producing multi-thematic maps and outlining the limiting factors, accordingly suitable suggestions that could be attained to understanding how to deal with these soils for sustainable agricultural use (Ali and Kotb, 2010).

All interpolation methods have been developed based on the theory that points closer to each other, have more correlations and similarities than those farther. In IDW method, it is assumed substantially that the rate of correlations and similarities between neighbors is proportional to the distance between them that can be defined as a distance reverse function of every point from neighboring points. It is necessary radius and the related power of the distance reverse function is considered as an important problem with this method. The main factor affecting the accuracy of inverse distance interpolation is the value of the power parameter (Yasrebi *et al.,* 2009).

The main goal of the current research is to use spatial analysis and Landsat ETM^+ imagery to obtain a detail soil mapping and assessment of land capability of the North Delta Egypt.

Material and Methods

Study area

The study area occupies a portion of the northern part of the Nile Delta - Egypt (Fig. 1) and extended from longitudes 30°35` and 31° 00` E and latitudes 31° 10` and 31° 28` N (Fig. 2), it covers an area of (720 km^2) including urban areas (6.25% of the total area).

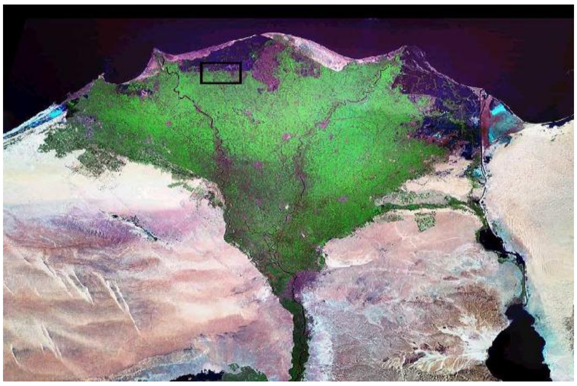

Fig. 1. Location of the study area.

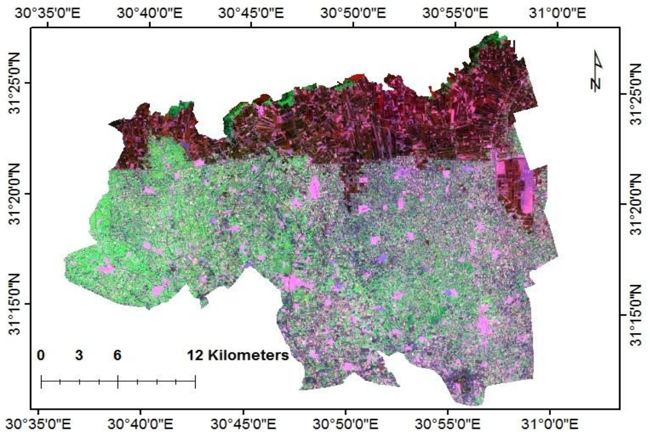

Fig. 2. Landsat ETM+ image of the study area.

The climatic conditions of the study area are arid to semi-arid, characterized by a long hot dry summer, mild winter with rainfall, high evaporation with moderately to high relative humidity.

Image possessing

Digital image processing of Landsat 7.0 ETM+ satellite images dated to the year 2010 was performed using ENVI 5.0© software (ITT, 2012) for classifying the geomorphologic units. The image analysis included, data calibration according to Lillesand and Kiefer (2007), data manipulation (image stretching, filtering, and histogram matching), atmospheric correction was done, rectification of satellite images, enhancing the ground resolution from 28.5 m to

14.25 m. Fusion methodology was applied according to Ranchin and Wald (2000) using ENVI 4.7 software.

Generation of ASTER DEM from ASTER images 3n (nadir) and 3b (backward) level 1b dated to 2005. To improve the accuracy of 25 meters, topographic map's scale of 1:50,000 were used. Additional spot heights collected from the field by using total station STONEX STS02 (accuracy 2 mm) were spatially added for deriving high resolution Digital Elevation Model (DEM) (Fig. 3).

Field work and laboratory analysis

Soil samples were collected from 45 soil profiles chosen carefully based on the soil classification map (Fig. 4), in the studied area in summer 2011. The soil profiles were thoroughly examined and morphologically described in the field, according to the system outlined by FAO (1990).

Physical analyses

Particle size distribution was determined according to Bandyopadhyay (2007). Bulk density was determined by Blake and Hartge (1986).

Chemical analyses

Soil Electric conductivity (EC), soluble cations and anions, $CaCO_3$, organic matter (OM), pH and sodium adsorption ratio (SAR), were determined according to Bandyopadhyay (2007).

Soil taxonomy

Soils of the studied area at the sub great group level were classified according to the rules of soil taxonomy (USDA, 2010).

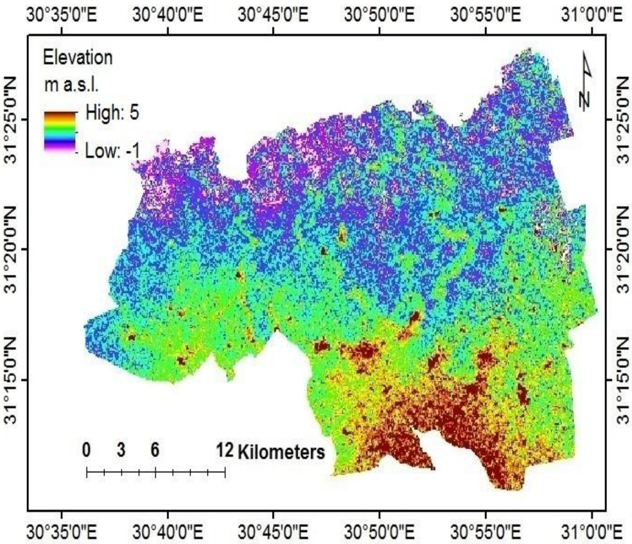

Fig. 3. Surface evaluation of the study area.

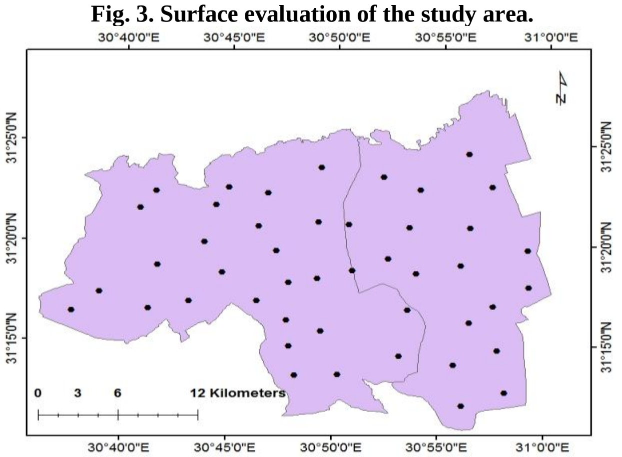

Fig. 4. Location of soil profiles.

Maps production

Inverse Distance Weighting (IDW) technique assumes that the (z) value (nonsampled point) is the distance-weighted average of neighbored known points (Zare-Mehrjardi *et al.*, 2010). The neighboring radius and the related power to the distance is a critical matter in this method. The IDW method is used in sites with sufficient data points; (at least 14); and in a suitable distribution (Yasrebi *et al.,* 2009). It is the most common interpolating methods in agriculture practices (Mishra, 2009).

ArcGIS 10.1 with its ArcGIS geostatistical and spatial analyst (IDW) extension, were used to create the thematic layers for the soil parameters of $CaCO_3$ and clay content, water table (WT) depth, EC, pH, SAR, OM. and bulk density (Bd). The interpolation methods depend on the fact that the more closed points are more correlated and similar (Yasrebi *et al.,* 2009). The spatial analysis function was used to reclassify the thematic layers, and then areas of the different levels of soil parameters were estimated.

The above classified layers were used to assess the land capability, where the weighting value is considered as similar for all soil parameters. The following formula was applied:

(Ci) = A*/100* B/100* C/100* D/100* E/100* F/100* G/100* H/100*

where Ci = Capability index for irrigation; A = $CaCO_3$ content, B = Clay content, C= Watertable depth, D= electro-conductivity, E= pH, F= Sodium absorption ratio (SAR), G= Organic matter (OM), H= Bulk density.

The land capability classes were defined using the rating developed by FAO (2007).

Results and Discussion

According to the American soil taxonomy and climatic data the investigated area is characterized by the soil temperature regime is thermic and the soil moisture regime is aridic and torric. Landsat ETM^+ images, the Digital Elevation Model (DEM) and the ground observation, were used to define the physiographic units in the study area according to Bobos *et al.* (2002) as shown in Fig. 5.

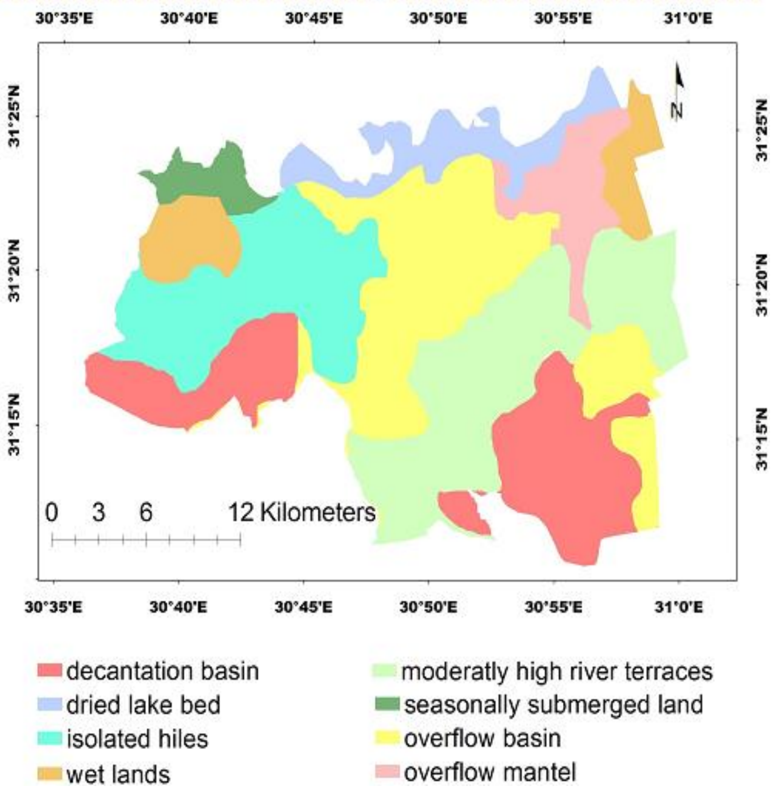

Fig. 5. Physiographic map of the study area.

Results indicate that the major landscapes in the studied area are the flood plain and fluvio-lacustrine plain. Flood plain is the main landform in this area which contains different landforms of moderately high river terraces, isolated hiles, overflow basin, overflow mentel and decantation basin. Their covering areas are 18.57, 14.8, 27.5, 2.09 and 26.79 %, respectively. Relief types in the flood plain are flat and almost flat. These soils were classified as Typic Torrifluvents, Vertic Torrifluvents, Typic Haplosalids and Aquallic Salorthids sub great groups as shown in Fig. 6.

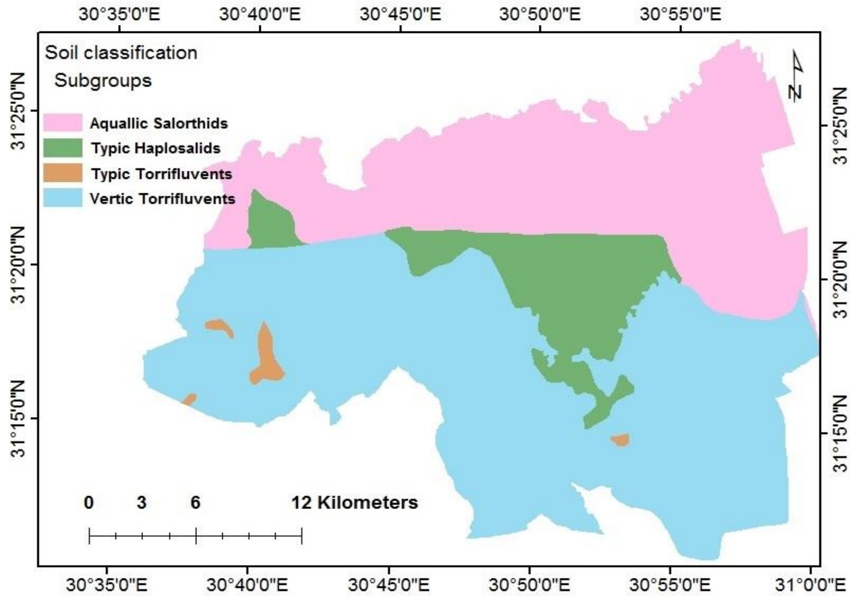

Fig. 6. Soil classification of the study area.

Fluvio-lacustrine plain include the following: wet lands, dried lake bed and seasonally submerged land, and they represent 6.5, 2.47 and 1.28 % of the total area. The dominant relief type in this plain is flat or almost flat. The main taxonomic unit in this landscape is Aquallic Salorthids. These results are in agreement with Darwish and Abdel Kawy (2008).

TABLE 1. Rank and rating classes of the different soil characteristics.

Rank values	$CaCO_3$ (%)	WT (cm)	Soil texture (class)	EC (dS/m)	SAR	Bd gm/cm3	OM (%)	pH
0-0.01	--	--	--	--	--	--	--	--
0.01-0.6	>30	<60	S	>16	>40	<2	<0.5	>9.5
0.61-0.7	15.30	60-80	SiC, C	8-16	20-40	1.5-2	0.5-1	9-9.5
0.71-0.9	8-15	80-100	CL, LS	4-8	10-20	1.2-1.5	1-2	8-9
0.91-0.96	4-8	100-150	SL, CL	2-4	5-10	1-1.2	2-4	7.5-8
0.97-1	0-4	>150	L, Si, SCL	<2	<5	<1	<4	6-7.5

Land capability assessment

Using ArcGIS 10.1 extension, spatial analyses techniques to assess the agricultural land capability. The landforms of the studied area were defined by using the digital elevation model, Landsat ETM+ images and soil survey data. The produced map, represents the landforms, was imported in a Geo-database and considered as a base map.

The attributed data of clay and $CaCO_3$ content, water table depth (WT), electrical conductivity (EC), pH, sodium adsorption ratio (SAR), organic matter (OM) and bulk density (Bd) condition were analyzed by (IDW) and linked with the units of the digitized geomorphologic map in a Geographic Information System (GIS). Inverse Distance Weighting interpolation gives weights to sample points, such as the influence of one point on another decline with distance from the new point being estimated, to obtain the thematic layers of spatial distribution of the above mentioned characteristics as shown in Fig . 7 to 14 and Table 2. The created layers include information on capability subclass, and spatial distribution for the soil characteristics. The obtained data indicated that the main limiting factors in the studied area were the water table depth, soil salinity, clay content, pH, SAR, organic matter and bulk density.

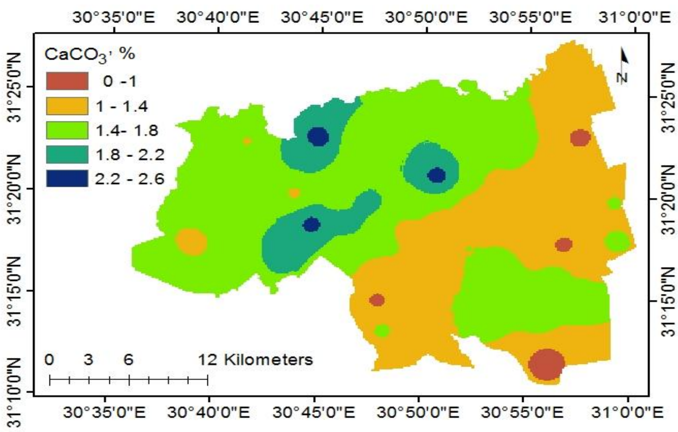

Fig. 7. Spatial distribution of CaCO3 content.

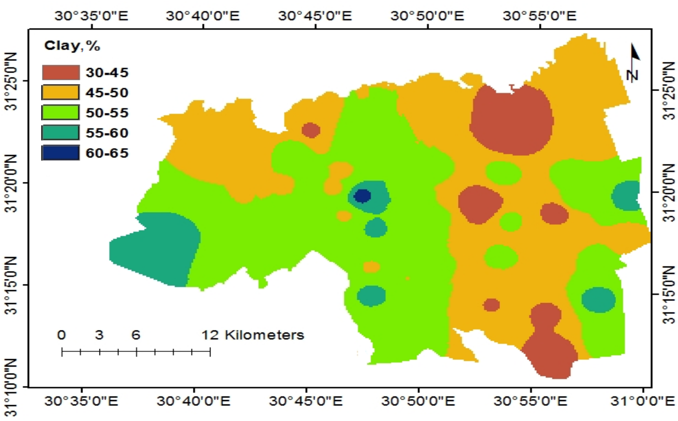

Fig. 8. Spatial distribution of clay content.

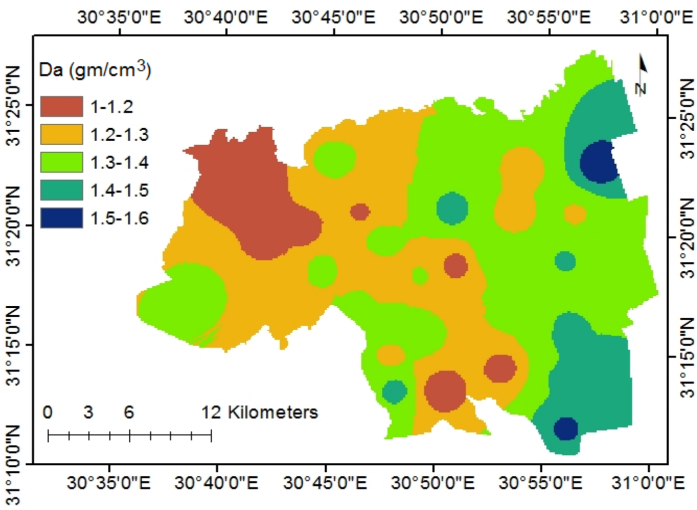

Fig. 9. Spatial distribution of bulk density.

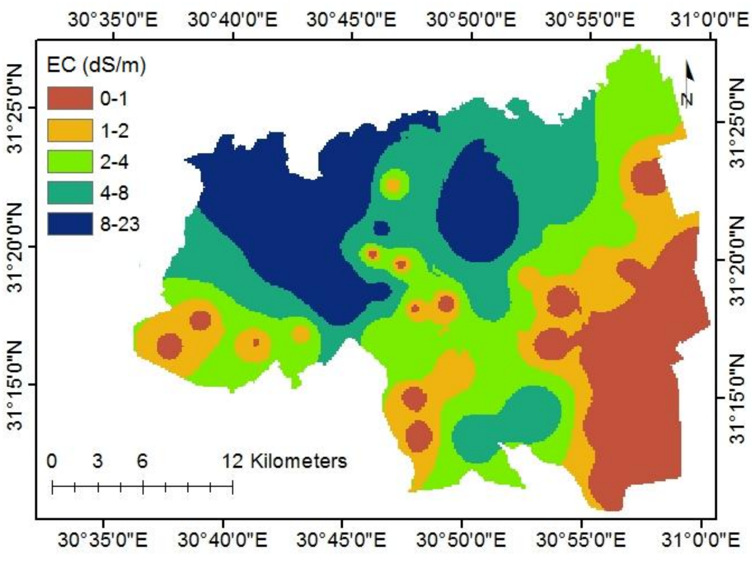

Fig. 10. Spatial distribution of electrical conductivity.

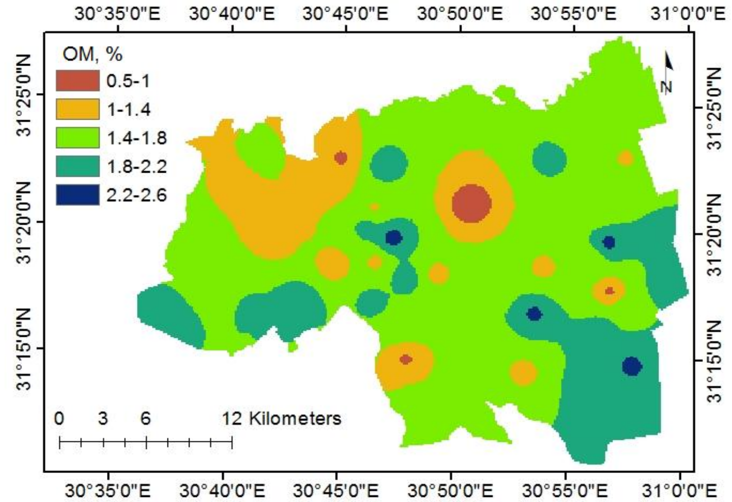

Fig. 11. Spatial distribution of organic matter content .

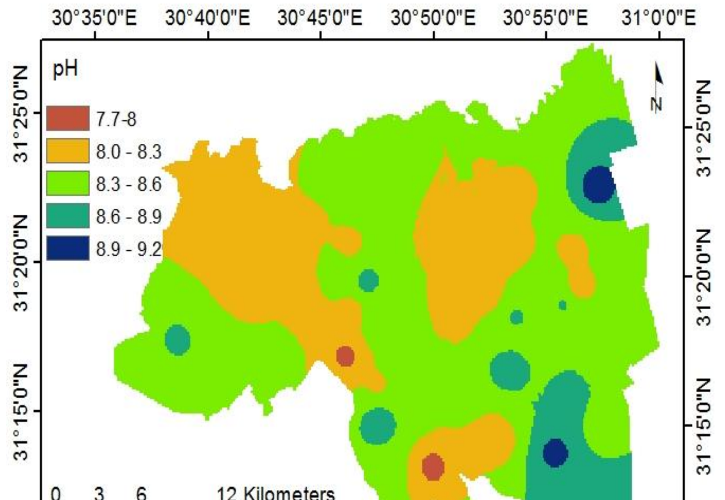

Fig. 12. Spatial distribution of pH content .

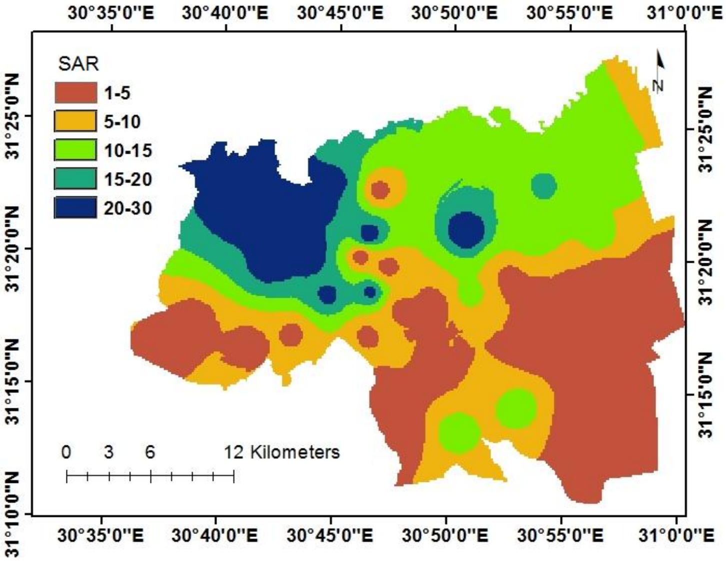

Fig. 13. Spatial distribution of sodium adsorption ratio .

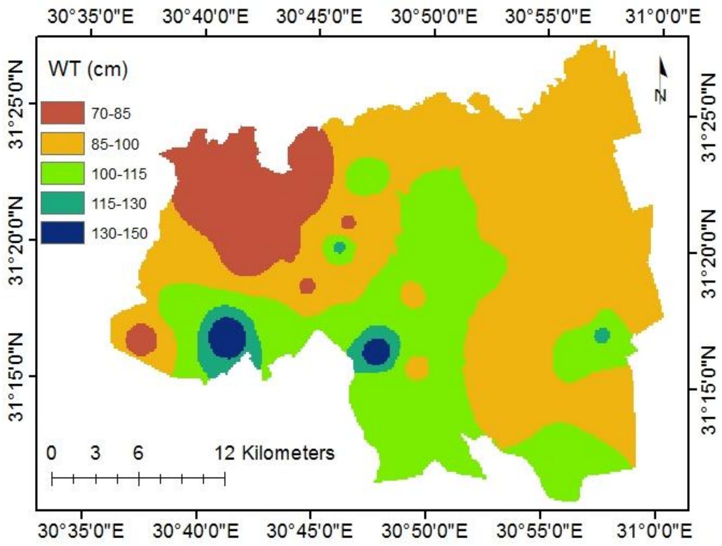

Fig. 14. Spatial distribution of watertable level.

TABLE 2. Areas of the levels of soil parameter .

Soil parameter	Level	Area km^2	% of total area
$CaCO_3$,%	0-1	10.60	1.47
	1-1.4	274.21	38.09
	1.4-1.8	362.42	50.34
	1.8-2.2	67.58	9.38
	2.2-2.6	5.18	0.72
Total		**720**	**100**
Clay, %	30-45	62.14	8.63
	45-50	291.22	40.45
	50-55	315.15	43.77
	55-60	50.27	6.98
	60-65	1.22	0.17
Total		**720**	**100**
Bd, (gm/cm^3)	1-1.2	76.86	10.68
	1.2-1.3	243.51	33.82
	1.3-1.4	303.36	42.13
	1.4-1.5	86.51	12.01
	1.5-1.6	9.76	1.36
Total		**720**	**100**
EC, (dS/m)	0-1	122.30	16.99
	1-2	111.03	15.42
	2-4	174.95	24.30
	4-8	171.52	23.82
	8-23	140.20	19.47
Total		**720**	**100**
OM, %	0.5-1	7.57	1.05
	1-1.4	117.94	16.38
	1.4-1.8	434.10	60.29
	1.8-2.2	156.37	21.72
	2.2-2.6	4.02	0.56
Total		**720**	**100**
pH	7.7-8	152.79	21.22
	8-8.3	248.19	34.47
	8.3-8.6	182.25	25.31
	8.6-8.9	117.05	16.26
	8.9-9.2	19.72	2.74
Total		**720**	**100**
SAR	1-5	187.68	26.07
	5-10	147.26	20.45
	10-15	147.51	20.49
	15-20	137.32	19.07
	20-30	100.22	13.92
Total		**720**	**100**
WT (cm)	70-85	108.71	15.10
	85-100	290.30	40.32
	100-115	206.63	28.70
	115-130	97.87	13.59
	130-150	16.49	2.29
Total		**720**	**100**

The limiting factors of water table depth, pH, OM, EC and clay content are associated with the floodplain, while the water table depth, pH, OM, EC, clay content, bulk density and SAR are the main limiting factors in the fluvio-lacustrine plain. These results are of importance as they show the dissemination of the constraints of productivity all over the region in the studied area.

The land capability was classified into four classes (class 1 to class 4) which represent 6.3, 28.95, 60.57 and 4.18 %, respectively, of the total area (Fig.15), according to the rating values (ranges from 0 to 1), as the soil capability class is 1 when the rating value is closed to 1. It is of interest to refer that the high capable soils (class 1 and class 2) dominate the flood plain and the low capable soils (class 4) dominate in fluvio-lacustrine plain near Burullus Lake.

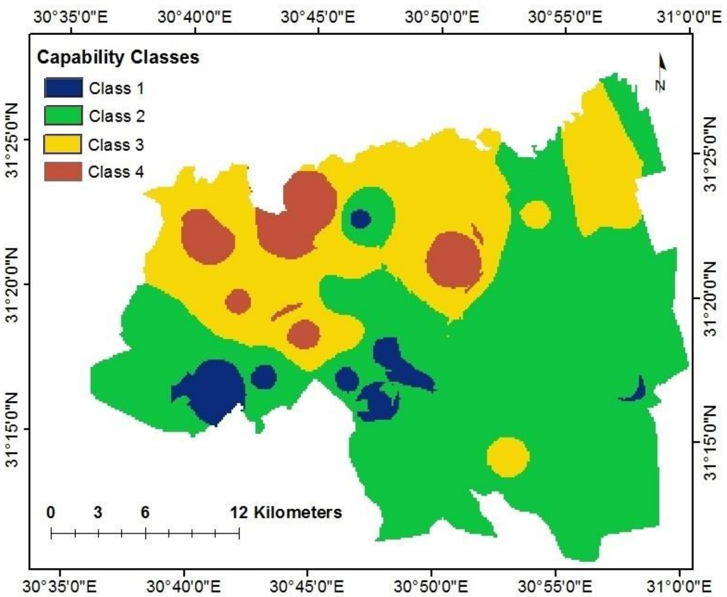

Fig. 15. Land capability in the studied area.

Conclusions

Using methods, inverse distance weighting method is useful to identify land capability classes for decision-making intervention. The studied area has been classified into class I, II, III and IV. Most of the area is defined to Class II and III, which are much suitable for agriculture accounting 28.95 and 60.57 percent. Class IV is the dominate class as far as the areal extent is concerned with 4.18 percent. The class IV is the most susceptible to land degradation and have very severe limitations, *i.e.* salinity and soil depth, hence careful selection of crops and conservation practices in the study area are required.

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تقييم القدرة الانتاجية للأراضي باستخدام نظم المعلومات الجغرافية في شمال الدلتا ، مصر

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تتزايد مشاكل السكان بتزايد اعددهم باطراد مما يؤدى الى زيادة الضغوط على الاراضى الزراعية وخصوصا في منطقة دلتا النيل - مصر، الأراضي الزراعية في مصر محدودة، وأدى الضغط الهائل عليها الى تقلص الموارد الارضية. ولذلك فإننا بحاجة إلى تحديدها والمحافظة عليها للاستخدام الزراعى. وتهدف هذه الدراسة إلى إعداد خرائط موضعية لخصائص التربة من خلال أستخدام اسلوب التحليل المكانى (analysis technique spatial) وتقييم القدرة الانتاجية للاراض بمساعدة نظام المعلومات الجغرافية (GIS).

لتحقيق هذا الهدف تم استخدام بيانات الدراسة الميدانية، والتحاليل المعملية وبيانات صور الاقمار الصناعية (Landsat ETM+ and ASTER images) في نظام المعلومات الجغرافية لتحديد أشكال سطح الأرض والقدرة الانتاجية للاراضى فى منطقة الدراسة. وتم تجميع عينات التربة الممثلة حسب أشكال سطح التربة جنوب بحيرة البرلس شمال دلتا النيل - مصر.

تم تحديد الوحدات التصنيفية للتربة وهى (Aquallic Salorthids, Typic (Haplosalids, Typic Torrifluvents and Vertic Torrifluvents ومثلت 31.97 – 13.48 – 1.25 – 53.3 % من المساحة الكلية على التوالي. والاشكال الرئيسية للتربة هى flood plain and lacustrine plain (74.7 و25.3 من المساحة الاجمالية).

خرائط خصائص التربة لكربونات الكالسيوم ومحتوى الطين وعمق مستوى الماء الارضى والتوصيل الكهربى ورقم حموضة التربة ونسبة الصوديوم المدمص والمادة العضوية والكثافة الظاهرية تم انتاجها باستخدام برنامج نظام المعلومات الجغرافية ArcGIS 10.1 باستخدام طريقة Inverse Distance Weighting (IDW). تم دمج خرائط الصفات السابقة معا لتقييم درجات القدرة الانتاجية للارض. تالفت القدرة الانتاجية للارض المدروسة من 4 درجات وهى اراضى الدرجة الاولى والثانية والثالثة والرابعة بنسبة 6.30 – 28.95 – 60.57 – 4.1 ٪ على التوالى.