CHARACTERIZATION AND EVALUATION OF COASTAL ECOSYSTEMS USING GIS/RS/MODELING INTEGRATED APPROACH: A CASE STUDY IN EGYPT.

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ABSTRACT

The coastal areas, the places where the sea water meets the land, are indeed unique places in our global geography. They are endowed with a very wide range of coastal ecosystems like mangroves, coral reefs, lagoons, sea grass, salt marsh, estuary etc. Further, Geographical Information System (GIS) and Remote Sensing (RS) are used in analyzing the trends and estimating the changes of different themes. The study area covers about 4867 feddans situated at Mutubas and El-Burullus districts, Kafr El-Sheikh governorate, Egypt. The study site included two villages namely, Ibrahim El-Desoky and El-Sayed El-Badawi. One hundred sixty five soil profiles were dug to depth ranging from 60cm to 150cm depending on water table level, to characterize the soils. The results showed that the main texture classes were sandy loam and loamy sand, there were seven main soil units covering the study area, representing 7.25%, 23.68%, 17.13%, 33.24%, 1.04%, 6.25%, and 0.79% of the total area, respectively. The two village residential areas cover about 10.62% of the total acreage. The dominant capability class in the study area was C3, which covered about 88% of the total area with three main limitations, namely: soil texture, available water content and soil salinity. The use of multitemporal satellite images acquired at 1985 and 1999 showed that the main land use/land cover classes were bare sandy soil and sand dune representing an area about 75.73%, 13.65% and 55.70%, 33.68% respectively. While, the satellite image acquired at 2002 showed that the main land use/ land cover classes were bare sandy soil, cultivated land and villages building covered about 49.64%, 39.92% and 10.52% respectively. GIS terrain analysis showed that the elevation above sea level ranged from 0 to 775cm. The DEM was analyzed to obtain the different scenarios of sea level rise, and map overlay was used to obtain areas of soil units and land use classes susceptible to disappearance according to each sea level rise scenario. The results showed that by increasing sea level rise, the areas of different soil units and land use classes subject to inundation will be increasing. At 25 cm sea level rise, 0% of the cultivated lands will be submerged, while increasing the sea level rise to 200 cm will cause 10 % of the cultivated lands to submerge in addition all the two villages' buildings will disappear.

Key words: *coastal ecosystem, GIS/RS, change detection, sea level rise, modeling, land evaluation.*

INTRODUCTION

The coastal ecosystems are of great importance and of immense value to mankind in the present and in the future. They are being degraded at an alarming rate by various preventable activities including that of human interference. The coastal ecosystems are to be monitored periodically for better management plans. The satellite based sensors provide valuable information useful in assessment, monitoring and management of the coastal ecosystems. Optical remote sensing data is very useful for mapping the coral reef, mangrove and lagoon ecosystems. The information, which is thus derived, can be very useful in the coastal ecosystem management, which is greatly required for the sustainable use, development, and protection of the coastal and marine areas and resources. Thus remote sensing and GIS technologies are widely used today in coastal ecosystem management (Ramachandran et.al., 1997, 1998). Land evaluation is a great importance in guiding decisions on land uses in terms of their potential and conserving natural resources for future generations.

Local development plans are quite hard to implement and monitor in fast changing, developing areas without the help of modern space and information technologies. High resolution, multi-temporal dimensions of satellite imaging quickly help to establish the regions of fast deviations where more attention and control can be paid. Such monitoring and timely evaluation will definitely help provide more realistic, ecologically sustainable, sound implementations and timely revisions of economic development efforts. Much more effective support to sustainable land use / land cover (LU/LC) planning is expected from the spectrally and geometrically higher resolutions of the newer generation of sensors (Hülya, et. al., 2002).

Orhan et. al., (2003) showed that in addition to field studies, digital soil and land use related data (satellite data, DEM and digital geology maps) were used and analyzed with remote sensing (RS) and geographic information systems (GIS) techniques and a new digital soil map and database were generated for the study area. RS and GIS techniques were successfully applied in land evaluation study. Aggag et. al., (2006) used coupling GIS and micro-computer program for land evaluation to study the soil of El-Sharkeya governorate, Egypt and they found that the soils are suitable for all crops and the only limited factor was the sandy texture which could be reduce its effect by applying optimum agricultural management practices.

Coastal risk to enhanced sea level rise and storm surge depends on not only the sensitivity of natural coastal system and the frangibility of the socio-economic factors, but also on the protection measures have to be taken. Zubair (2006) examined the ability of GIS and Remote Sensing in capturing spatial-temporal

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data. Attempt was made to capture as accurate as possible five land use / land cover classes as they change through time. However, the result of the work shows a rapid growth in built-up land between 1972 and 1986 while the periods between 1986 and 2001 witnessed a reduction in this class. It was also observed that change by 2015 may likely follow the trend in 1986/2001 all things being equal. Abo El-Ghar and Tateish (2002) using different satellite images to asses the change of land cover / land use for the eastern Nile delta of Egypt and they found that: a) the urban settlements increased considerably with high rate of annual increase every year; b) slight increase in the total cultivated area while the annual rate of agricultural soil reclamation decreased significantly in the last few years; c) the rate of change for desert areas is stable. Bahnassy. (2002) study different scenarios of sea level rise (25 cm, 50 cm, 75 cm and 100 cm) on the submergence of different soil units and land uses of Mutubas district, Kafr El-Sheikh governorate, Egypt. Landsat 7 image acquired on Dec. 1999 was processed to identify the major land uses in the study area. The DEM was analyzed to obtain the different scenarios of sea level rise, and map overlay was used to obtain areas of soil units and land use classes susceptible to disappearance according to each sea level rise scenario. The results showed that increasing sea level rise, will be increasing the areas of different soil units and land use classes subject to inundation. At 25 cm sea level rise, 47% of the cultivated lands will submerged, while increasing the sea level rise to 100 cm will cause 90 % of the cultivated lands to disappear.

The main goals of this study are to 1- Build-up geoinformtion supporting decision system, 2- Quantify change detection due to agricultural development using satellite data of different dates, 3- Assess the optimum land use using micro computer program for land evaluation (capability and suitability for different crops), and 4- Study the impact of sea level rise resulted from global warming.

THE STUDY SITE

The study area is located in two districts at Kafr El-Sheikh governorate namely; Mutubas and El-Burullus which are coastal districts. It is sited on the northeastern bank of Rosetta Nile branch. It is surrounded by the Mediterranean Sea to the north, Mutubas district to the west, Lake Burulus to south, and El-Burulls district to the east (map 1). The study site has a total acreage of 4867 Feddans.

METHODOLOGY

Datasets: The data used in this study were obtained from different sources as shown in (Fig. 1), 1- Topographic maps (1:50000) were georeferenced and digitized (TerraSoft GIS software, 1991), to obtain contour lines, boundary of the study area. The resulted map layers were exported to the Arc View GIS software (ESRI 1997) for further analysis. 2- Three Landsat satellite images were analyezed; Multi Spectral Scanner (MSS) acquired on 1985, Thematic Mapper (TM) of 1999 and Enhanced Thematic Mapper (ETM+) of 2002; were geometrically rectified to the topographic map. 3- Soils data were obtained from field survey and digging of 165 soil profiles (map 2). The profiles were geolocated by GPS (Garmin 1996), morphologically described (FAO 1990) were sampled to be chemically analyzed (Page et al. 1982) and physically characterized (Klute, 1986).

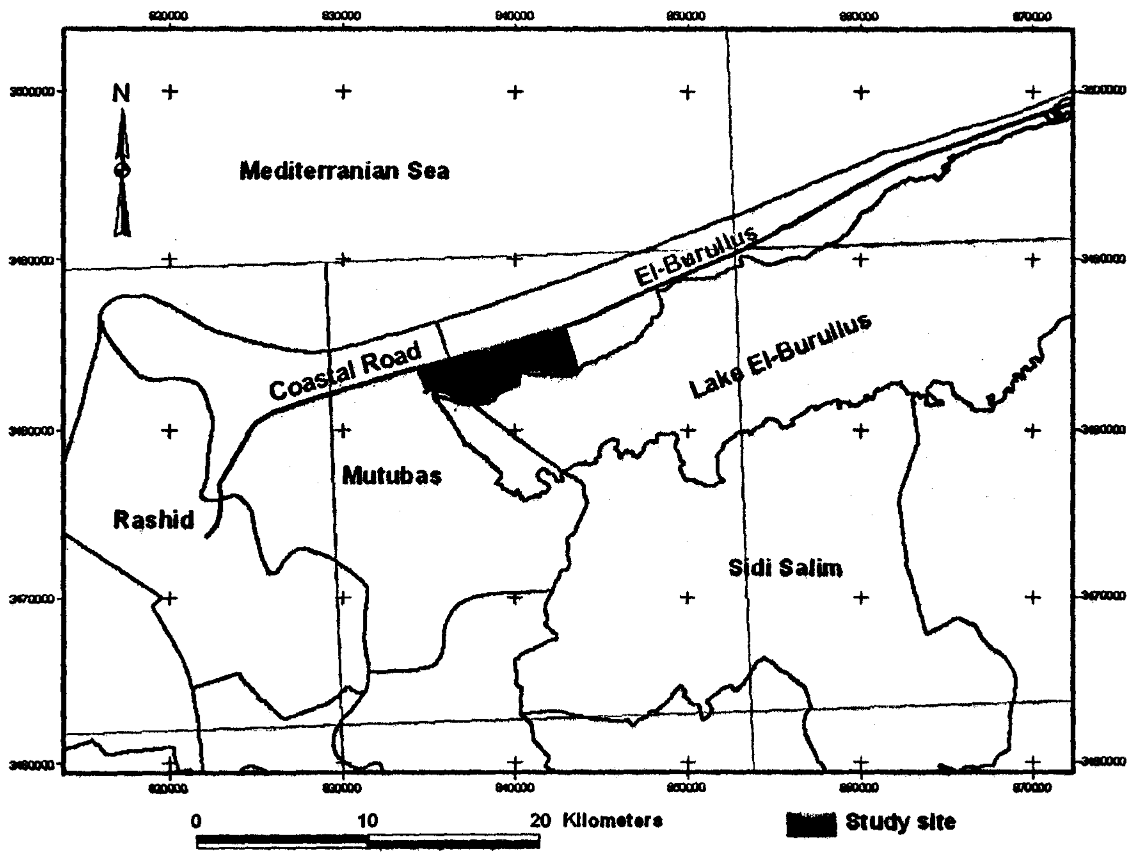
Land Use Classification: The satellite images were classified to obtain spectral classes that were interpreted to map the land use/land cover classes. The obtained classes represent the 3 major land uses dominated in the study area.

Digital Elevation Model (DEM) Analysis: Digitized contour lines were exported to ArcView GIS software to generate the DEM. The module Interpolate DEM was utilized to interpolate contours and produce the elevations. Slope and aspect were generated to characterize the topography of the study area. The DEM was reclassified to obtain different sea level rise scenarios (25 cm, 50 cm, 75 cm, 100cm, 150cm and 200cm). The resultant maps were cross-tabulated with both land use/land cover and land units maps in order to get the areas of different units subject to submergence by sea level rise.

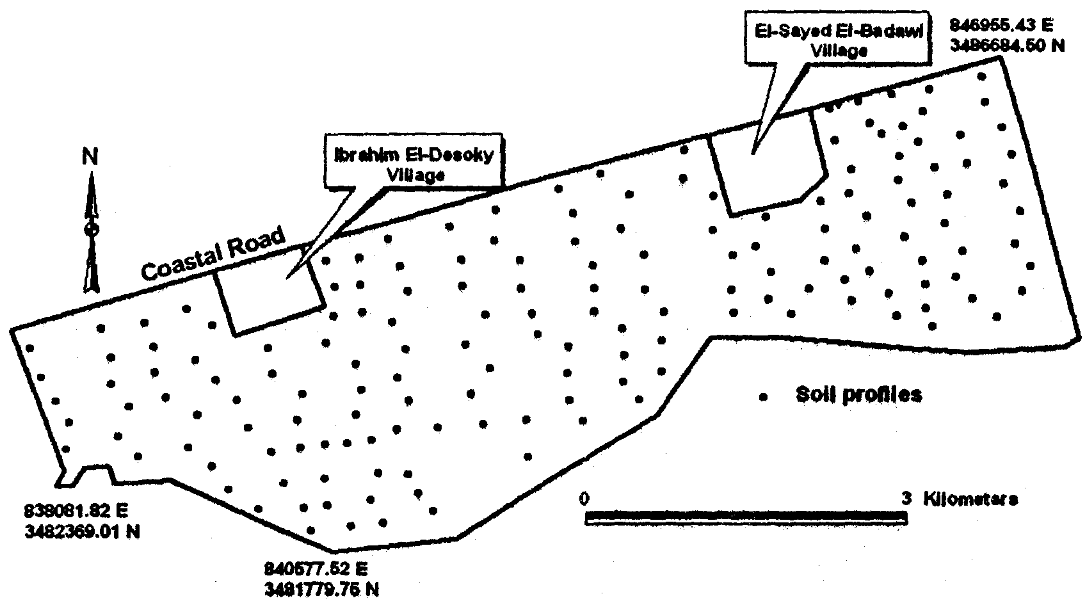
Land Evaluation: Agricultural Land Evaluation System for arid region (ALES-Arid) is a new approach for land capability and suitability evaluation (Abdel Kawy, 2004). ALES-Arid is described as a land use decision support system, which is linked indirectly with GIS. Through ALES-Arid program, land evaluation algorithms were expressed in notation forms that can be understood average user. Soil productivity classes were identified as Storie (1964) shown in table (1).

Table (1): Productivity classes and ratings according to Storie, 1964.

Class	Description	Rating (%)
C1	Excellent	80 – 100
C2	Good	60 – 80
C3	Fair	40 – 60
C4	Poor	20 – 40
C5	Very poor	10 – 20
C6	Non-agriculture	< 10



Map (1): General location of the study area.



Map (2): Overlay of soil profiles location on the study area.

The calculation of capability index by ALES-Arid is an indication of land capability according to multiplication method. ALES-Arid evaluates the suitability for 32 crops (field crops, vegetables, forage crops, and fruit tress) to identify the optimum land use. Land suitability classes were identified using the matching between standard crop requirements (FAO, 1977, 1985; Sys, 1975; and Sys *et al.*, 1993a, 1993b) and land characteristics.

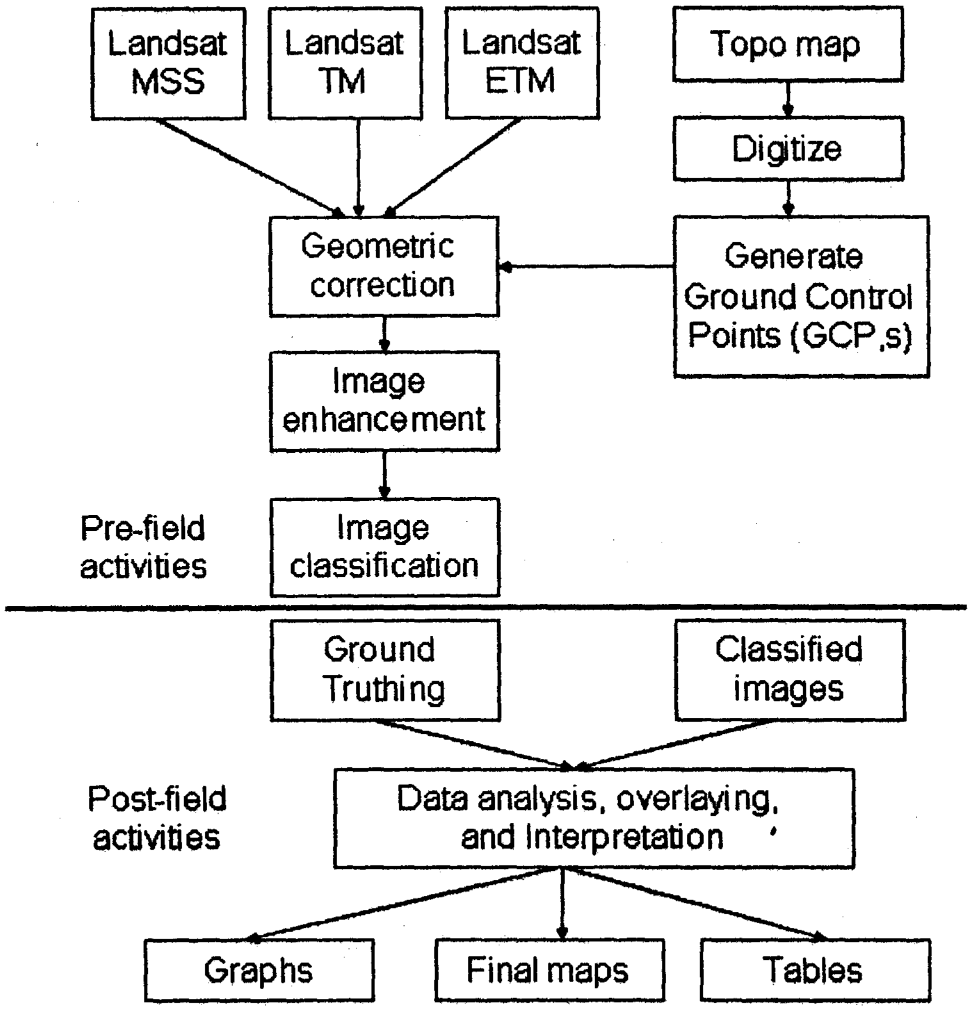


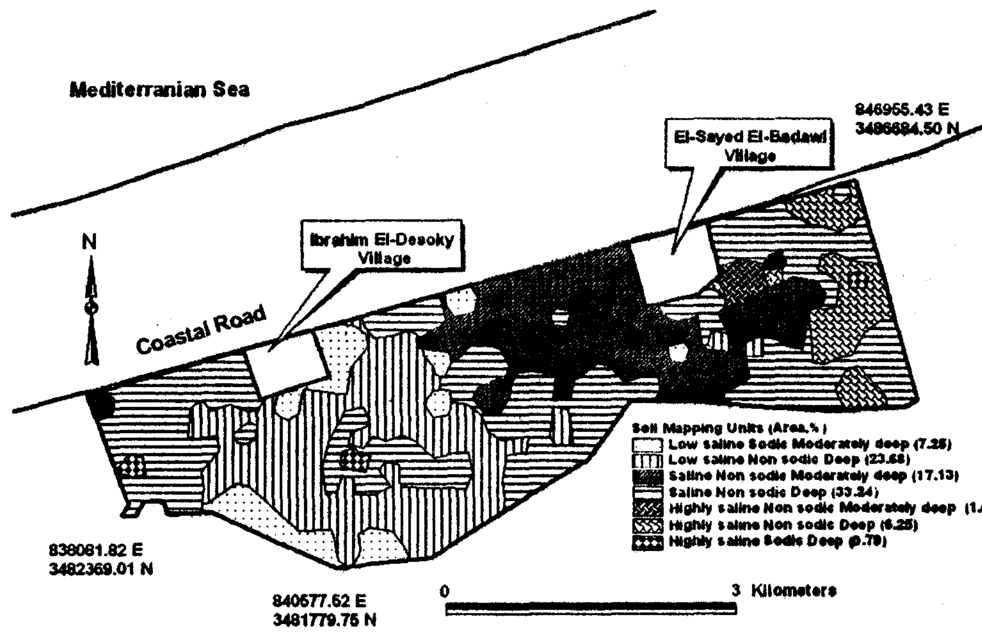
Figure (1): Flow chart representing the methodology.

RESULTS AND DISCUSSIONS

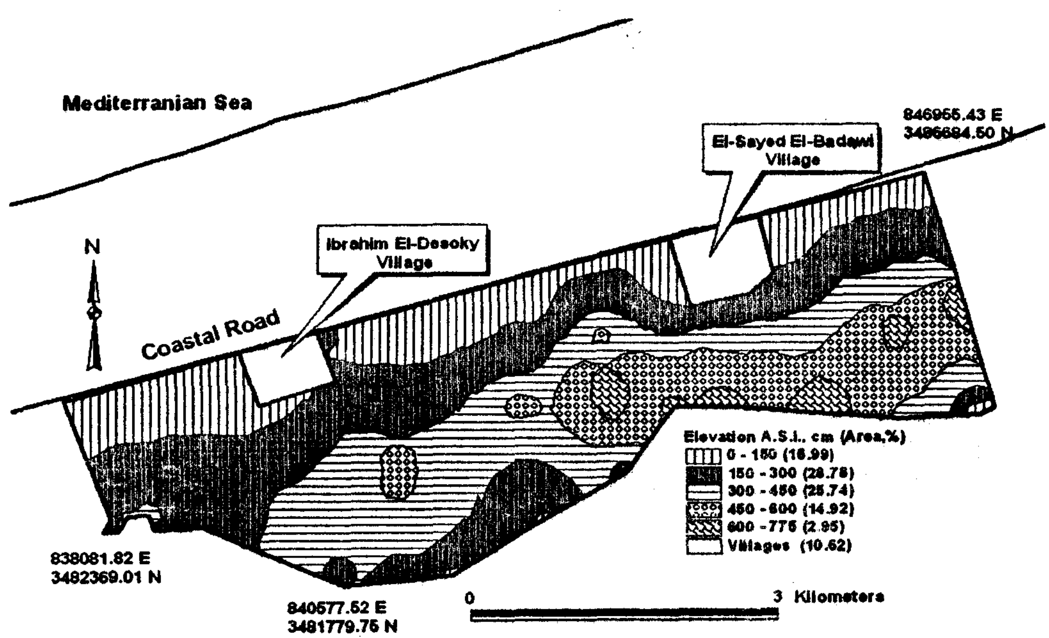
Soil characteristics: the overlay of different soil attribute layers in GIS environment showed that the study area have seven main soil units, namely low saline sodic moderately deep, low saline non sodic deep, saline non sodic moderately deep, saline non sodic deep, highly saline non sodic moderately deep, highly saline non sodic deep and highly saline sodic deep representing 7.25%, 23.68%, 17.13%, 33.24%, 1.04%, 6.25%, and 0.79%, respectively. In the same time, two village buildings (Urban areas) covers about 10.62% of the total area (map 3).

Topographic characteristics: DEM analysis indicated that most of the study area (28.78%) has elevations ranged from 150cm to 300cm above sea level, whereas elevations 300 – 450cm have about 25.74% of the total acreage, and elevations 0 – 150 cm have about 16.99% (map 4). The dominant slope class is flat (0 – 0.5) having about 95% of the total acreage, while dominant slope directions (aspect) are north, northeast, and northwest representing about 58% of the total acreage.

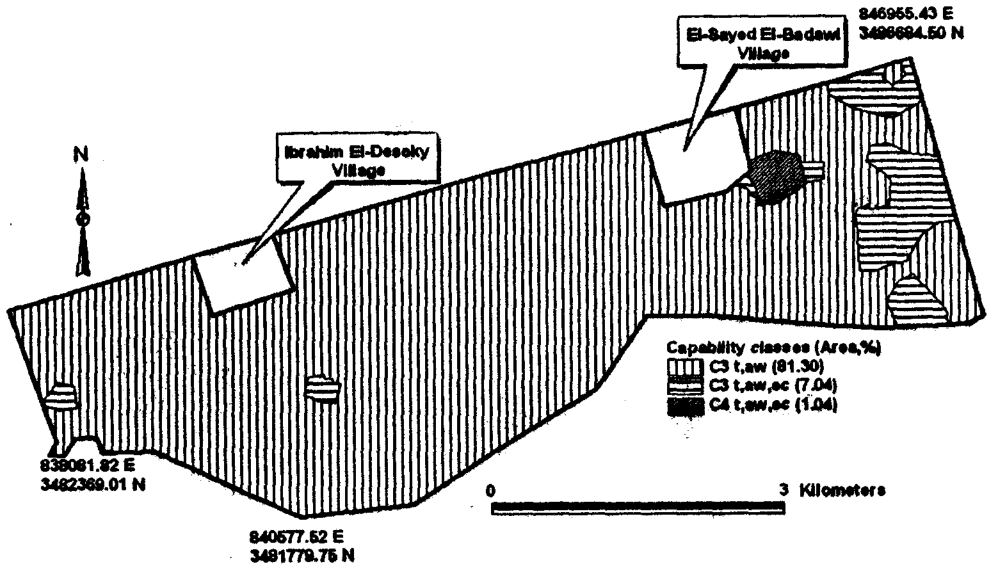
Land capability classes: The ALES-Arid model predicts general land use capability for a broad series of possible crop cultivation uses. According to the model prediction, most of the study area was classified as C3t, aw which indicated fair capability classes with soil texture (t) and available water percentage (aw) as limiting factors. That class covers 81.30%. While other classes were C3 (7.04%) and C4 (1.04%) with limiting factors as the previous factors with soil salinity. Map (5) illustrates the distribution and percentage of each land capability class of the study area.



Map (3): Soil mapping units of the studied area.

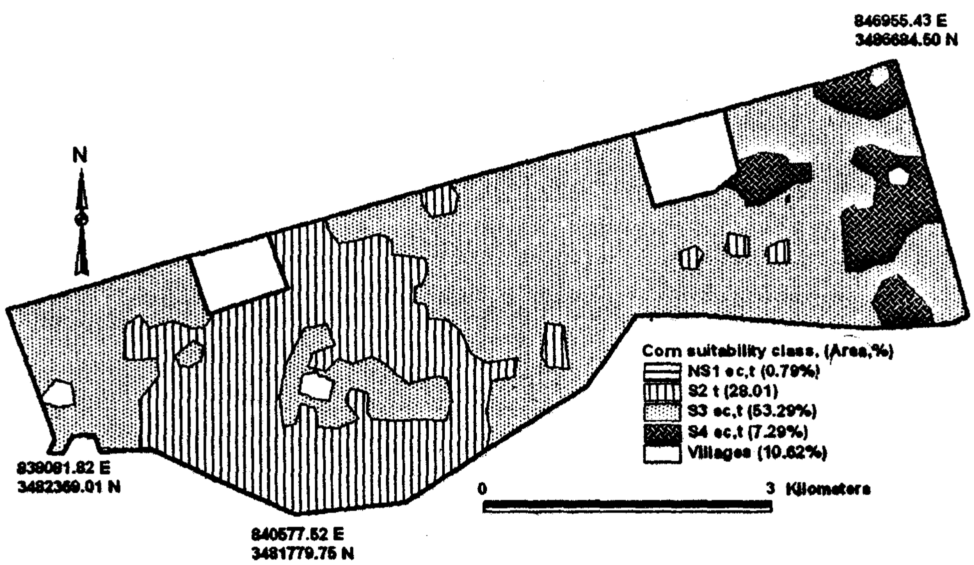


Map (4): Digital Elevation Model (DEM) for the study area.

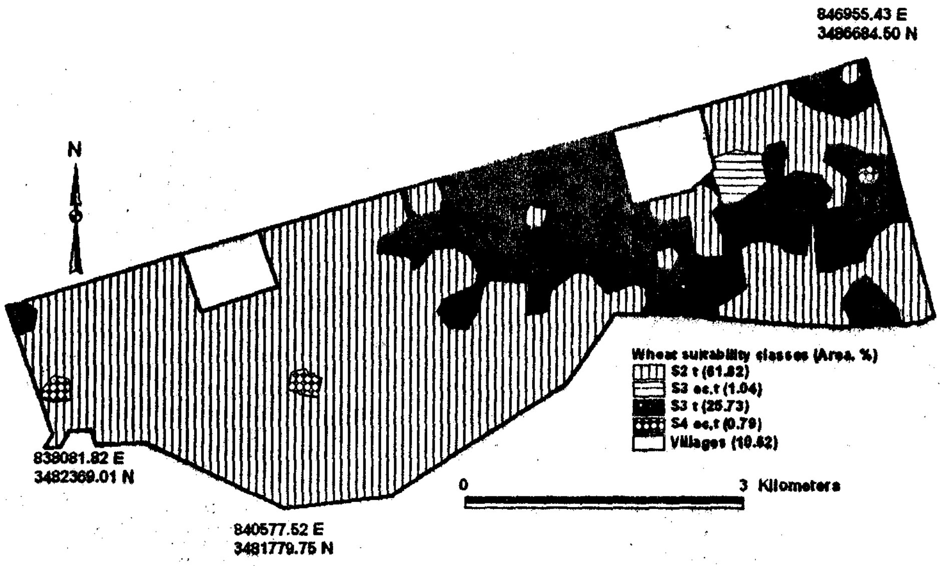


Map (5): Land capability classes.

Land suitability classes: The ALES-Arid Model was used to predict soil suitability for some common crops. Table (2) summarizes agriculture soil suitability classes for the selected crops and trees. Maps (6 and 7) show the suitability classes distribution for some crops which could be grown in the study area. The results showed that the soil mapping units coded 121, 131, 132, and 232 were not suitable for fruit tress due to the limited useful depth and the high soil salinity.



Map (6): Corn soil suitability classes



Map (7): Wheat soil suitability classes

Optimum land use planning: The suitability results of some mapping units showed that fruits were not suitable in those units due to high salinity, soil texture and soil depth limitations. For the summer season maize, potato and sunflower were suitable and for the winter season wheat and faba bean are highly suitable. Some soil units need more management practices such as amendment of organic materials to improve the soil texture and adding leaching requirements to reduce the soil salinity especially for the soil unit highly saline sodic deep (232) which cover about 0.79% of the total area (Table 2).

Change Detection: The processing and classification of three images acquired on 1985, 1999 and 2002, showed that there were two land use / land cover classes appeared in 1985 namely; bare sandy soil and sand dune, which covered about 86% and 14% of the total area respectively. In 1999, a new class (village buildings) occurred and occupied about 10.62% of the total area, and in 2002, the sand dune class disappeared and was replaced by cultivated land which covered about 39% of the total area (Fig 2).

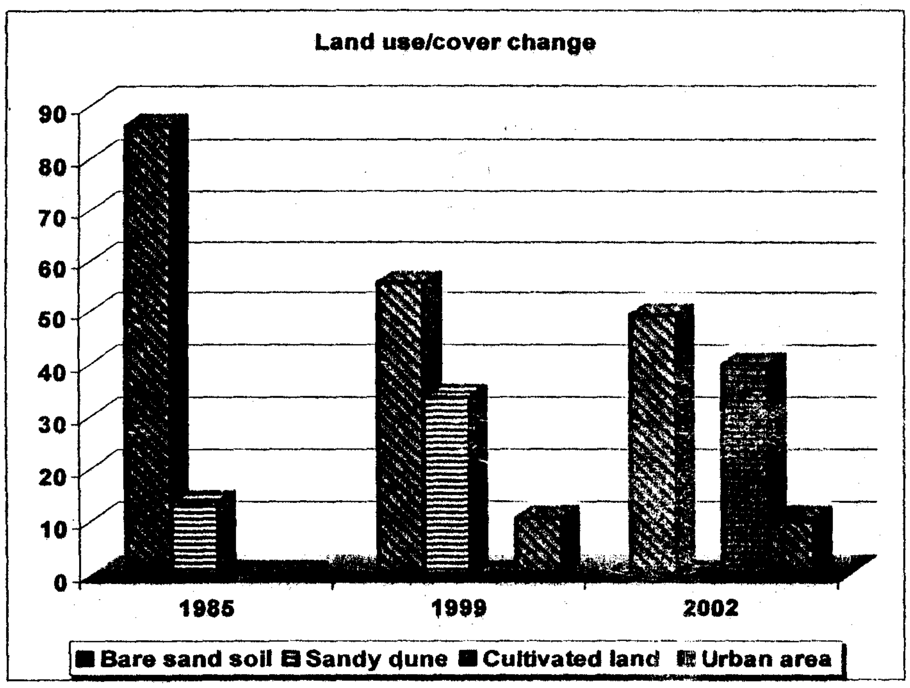


Fig (2): Land use / land cover change detection.

Table (2): Soil units and suitability class for each crop in the study area.

Crops	Soil units	Suitability Class	Crops	Soil units	Suitability Class
Wheat	111	S2t	Sugarcane	111	S3t
	112	S2t		112	S3t
	121	S3t		121	S4dp,t
	122	S2t		122	S3t
	131	S3ec,t		131	S4ec,dp,t
	132	S3t		132	S3ec,t
	232	S4ec,t		232	S4ec,t
Maize	111	S2t	Apple	111	S3dp,t
	112	S2t		112	S3t
	121	S3ec,t		121	NS2
	122	S3ec,t		122	S3ec,t
	131	S4ec,t		131	NS2
	132	S4ec,t		132	S4ec,t
	232	NS1ec,t		232	NS1ec,t
Faba Bean	111	S2t	Banana	111	S3dp,t
	112	S2t		112	S3t
	121	S4ec,t		121	NS2
	122	S4ec,t		122	S3ec,t
	131	S4ec,t		131	NS2
	132	S4ec,t		132	S4ec,t
	232	NS1ec,t		232	NS1ec,t
Sunflower	111	S3t	Sorgum	111	S2t
	112	S2t		112	S2t
	121	S3dp,t		121	S2t
	122	S2t		122	S2t
	131	S4ec,dp,t		131	S4ec,t
	132	S3t		132	S3ec,t
	232	S3t		232	NS1ec,t
Pea	111	S2t	Peanut	111	S1
	112	S2t		112	S1
	121	S4ec,t		121	S4ec
	122	S4ec,t		122	S4ec
	131	S4ec,t		131	S4ec
	132	S4ec,t		132	S4ec
	232	NS1ec,t		232	S4ec,t
Potato	111	S1	Pear	111	S3dp,t
	112	S1		112	S3t
	121	S3ec		121	NS2
	122	S2ec		122	S3ec,t
	131	S4ec		131	NS2
	132	S4ec		132	NS1ec,t
	232	S4ec,t		232	NS1ec,t
Soyabean	111	S3t	Citrus	111	S3dp,t
	112	S2t		112	S3t
	121	NS1ec,dp,t		121	NS2
	122	S4ec,t		122	S3ec,t
	131	NS1ec,dp,t		131	NS2
	132	S4ec,t		132	NS1ec,t
	232	NS1ec,t		232	NS1ec,t

Where 111= Low saline sodic moderately deep, 112= Low saline non sodic deep, 121= Saline non sodic moderately deep, 122= Saline non sodic deep, 131= Highly saline non sodic moderately deep, 132= Highly saline non sodic deep, and 232= Highly saline sodic deep.

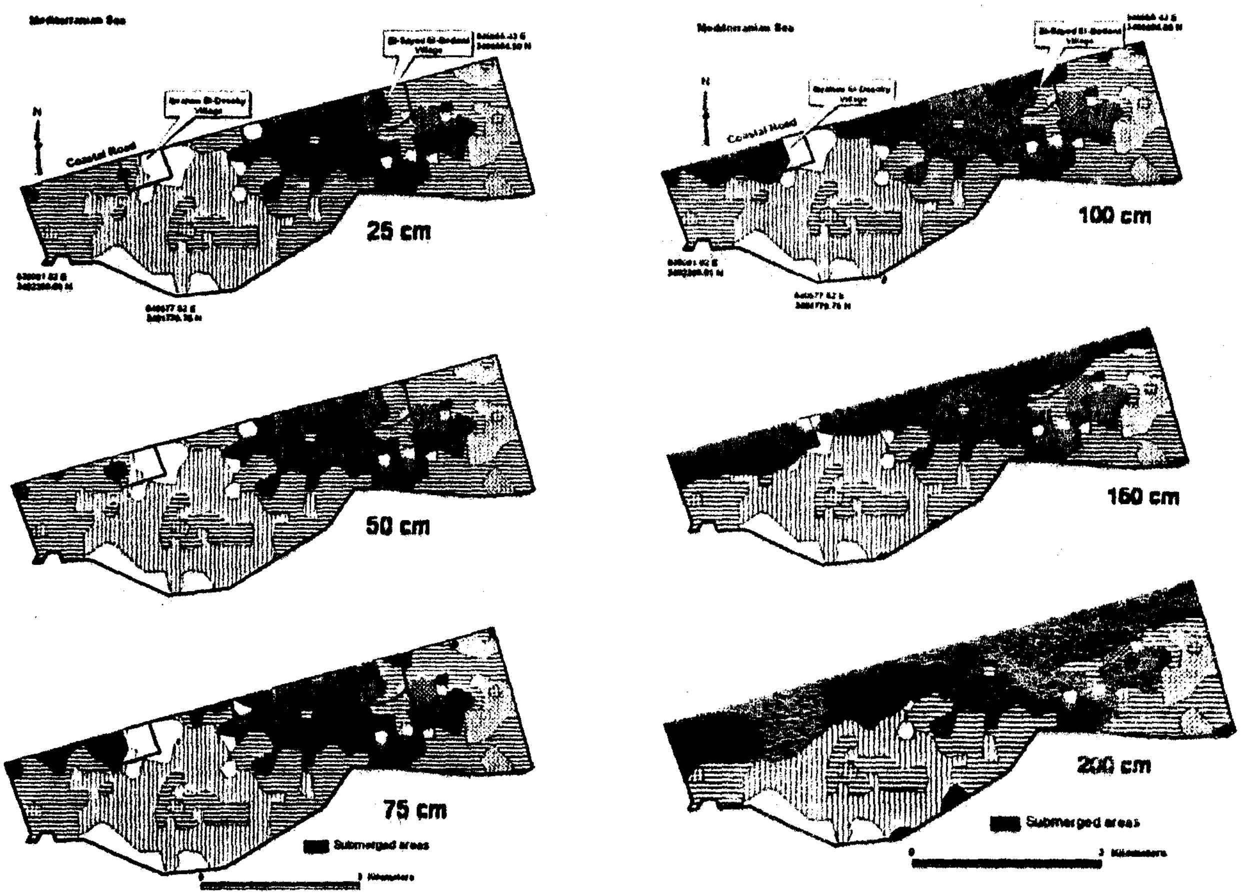
Impact of sea level rise

1- The effect on soil mapping units: The six scenarios of sea level rise indicated that the precious soils of the northern area are vanishing. By rising sea level, the percentage loss is increasing up to 100%, as the case of urban area at 2002 (table 3). The most vulnerable land units to submergence are the units which concerned in the northern part such as saline non sodic deep (122) followed by the saline non sodic moderately deep (121), then low saline sodic moderately deep (111), as these units will be reduced in area by 19.32%, 14.42%, and 6.43% respectively, as the sea level will rise by 100 cm. The losses increase for all mapping units as the sea level rise increases as shown in map 8.

2- The effect on land use / land cover: The main land uses in the study area are bare sandy soil, cultivated land and urban area. As the sea level rises 200cm, about 38% of the cultivated lands will vanish, as well as about 50% of the bare sandy soil, whereas urban area will disappear completely

Table (3): Percentage areas of potential submergence of soil mapping units due to different sea level rise scenarios

Soil Mapping Units	Area (Fed.)	% Loss due to sea level rise					
		25cm	50 cm	75 cm	100 cm	150 cm	200 cm
111	382.91	0.00	2.45	2.68	6.43	29.45	48.30
112	951.56	0.00	0.00	0.56	3.04	12.86	28.80
121	959.67	0.92	3.84	8.35	14.42	30.43	42.45
122	1659.85	0.49	2.23	10.69	19.32	30.89	41.58
131	50.74	0.00	0.00	0.00	0.00	5.91	51.95
132	304.04	0.00	0.00	2.04	4.79	18.40	26.92
232	38.48	0.00	0.00	0.00	0.00	0.00	6.68
Villages Buildings	516.53	1.45	5.51	15.02	25.77	46.13	100.00



Map (8): Potential impact of sea level rise on the submergence of soil units.

CONCLUSIONS

The coastal ecosystems are of great importance and of immense value to mankind in the present and future time. They are being degraded at an alarming rate by various preventable activities including that of human interference. An integrated geodatabase (biophysical and socioeconomic) should be prepared prior to reclamation and management of the coastal ecosystem, concentrating on DEM and its analysis, to assess the environmental impact of sea level rise due to climate change, in order to maintain the sustainable development of the coastal areas. In this case study, the jetty west of El-Burulus should be elongated, and the concrete wall has to be enforced, and more beach sands should be added. Moreover, the best agricultural crops should be selected to reach the maximum attainable profit from using the production unit of soil and water.

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الملخص العربى

توصيف وتقييم النظم البيئية الساحلية باستخدام تكامل نظم المعلومات الجغرافية والاستشعار عن بعد والنمذجة: دراسة حالة فى مصر

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تعرف المناطق الساحلية على انها اماكن التقاء مياه البحر مع اليابس وهى تعتبر من الاماكن الفريدة فى جغرافيتنا العالمية وهى تمثل الشعاب المرجانيه واعشاب البحر والمستنقعات والملاحات والمصبات... الخ. ويعتبر نظم المعلومات الجغرافية والاستشعار عن بعد من الادوات الاساسية التى تستخدم فى دراسة الانظمة البيئية الساحلية والتغيرات الحادثه بها. الاهداف الاساسية لهذه الدراسة هى بناء قاعدة بيانات رقمية متكاملة فى بيئة نظم المعلومات الجغرافية لدعم متخذى القرار بالمعلومات الكافية عن منطقة الدراسة.

ان استخدام صور الاقمار الصناعية المأخوذه على فترات زمنية مختلفة لتتبع التغيرات الحادثة بالمنطقة وتحديد الاستخدام الامثل لمنطقة الدراسة من حيث انواع المحاصيل التى تجود بالمنطقة لتحقيق التنمية الزراعية المستدامه ودراسة تاثير ارتفاع مستوى سطح البحر على الاراضى المتاخمة نتيجة للتغيرات المناخيه بالإضافة إلي العوامل الأخرى التى لها أهمية كبيرة في المناطق الساحلية المنخفضة وكيفية حماية هذه الانظمة من هذا الارتفاع.

تغطى منطقة الدراسة حوالى ٤٨٦٧ فدان وتقع بمركزى مطوبس والبرلس – محافظة كفر الشيخ – مصر، وتتضمن قريتى ابراهيم الدسوقى والسيد البدوى وللتعرف على خواص التربة تم حفر عدد ١٦٥ قطاع ارضى الى اعماق تتراوح من ٦٠سم الى ١٥٠سم. اوضحت النتائج ان قوام التربة السائد بالمنطقة هو اللومى الرملى والرملى اللومى وان هناك ٧ وحدات ارضية خرائطية رئيسية الى جانب مبانى القريتين وتمثل ١٠,٦٢% من اجمالى مساحة منطقة الدراسة. كما اوضحت نتائج تقويم التربة للقدرة الانتاجية هو C3 ويغطى مساحة تقدر بحوالى ٨٨% من اجمالى مساحة منطقة الدراسة وكانت المعوقات الاساسية هى قوام التربة وملوحة التربة وكذلك كمية الماء المتاح. كما اوضحت نتائج تحليل صور الاقمار الصناعية المتحصل عليها فى فترات زمنية مختلفة ان استخدامات الاراضى الاساسية لعامى ١٩٨٥ و١٩٩٩ كانت الاراضى الرملية والكثبان الرملية وتغطى فى الصورتين مساحات تتراوح من ٧٥,٧٣% ،١٣,٦٥% و٥٥,٧٠% ، ٣٣,٦٨% على التوالى اما بالنسبة لصورة القمر الصناعى المتحصل عليها عام ٢٠٠٢ كان الاستخدام الاساسى للتربة هو الاراضى الرملية الغير منزرعة والاراضى المنزرعة ومبانى القرى وتمثل مساحات تقدر بحوالى ٤٩,٦٤% و٣٩,٩٢% و١٠,٦٢% من اجمالى مساحة منطقة الدراسة على التوالى. ومن خلال تحليل نموذج الارتفاعات الرقمية اوضحت النتائج ان منطقة الدراسة تتراوح فيها الارتفاعات من صفر الى ٧٧٥سم فوق مستوى سطح البحر حيث تم استخدام نموذج الارتفاعات الرقمية لدراسة تاثير ارتفاع مستوى سطح البحر على اراضى منطقة الدراسة واوضحت النتائج انه نتيجة لارتفاع مستوى سطح البحر المتزايد سوف يؤدى ذلك الى اختفاء ١٠% من الاراضى الزراعيه وايضا اختفاء مبانى القريتين تماما اذا ارتفع مستوى سطح البحر الى ٢٠٠سم.