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D·tection and Evaluation of Land Degradation Along the Northern Coast of Egypt Using Multi Temporal Satellite Images

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THE STUDY area is located in the northern Mediterranean coast of Egypt between El-Hammam town, to the east and El-Alamean town, to the west. The area, from the seacoast to the Libyan plateau is composed of calcareous formation of Pliocene and Pleistocene ages, but covered by recent sediments. The wind and fluvial activities rework the sediments. The southerly dusty warm storms harm cultivation and cause soil water loss through its influence on increasing evapotranspiration. Also grazing and collection of plants for fuel, on large scale, have undoubtedly hindered the natural development of the vegetation and the soils. The current research aims to detect and assess the indictors of land degradation through the use of multi-nature remote sensing facilities and multi-temporal satellite images.

Two windows of SPOT XS satellite images dated 1988 and 1997 were digitally enhanced, geometrically corrected and classified. Field investigation was carried out on bases of the preliminary image analysis. Hyperid classification technique was generated using both ground truth and spectral classes.

A present state soil map was produced on basis of SPOT XS image of 1997 and field investigation. It was possible to drive out two reliable land use / land cover maps of years 1988 and 1997. Application of change detection technique on the two sets of data showed an increase in the area of saline and hyper saline soils from 1988 to 1997. Areas of vegetation, characterized by plant species that grow as short individuals, increased on expense of vegetation, characterized by plant species that grow as tall individuals. Resort houses and artificial limestone quarries as well as fig orchards that are maintained by medium to high level of agricultural replaced coastal dunes and other ridge components.

Keywords: Land degradation, Northern cost, Multi temporal satellite.

The problem of aridity extends mostly to 50% of the universe. Varieties of land degradation problems are related to physical, biological and socio-economic situation in arid lands and provoke stress on their natural resources. The common problem to all arid zones is the fragility of its ecosystem and the accompanying potential threat of desertification provoked, in most cases, by human intervention (UNESCO, 1977).

Remote sensing, with its multi-temporal nature provide the mean to detect dynamic phenomena and to deduce information about objects (Townshend, 1992). The use of high-resolution satellite images is almost promising to obtain reliable land cover/land use information (Dewbin and Fvurns, 1988). Also, soil associations, among natural resources, could be explored through space images (Biswas and Singh, 1991). Biswas (1986) stated that it is easier and more accessible to generate various soil, land and water resources data accurately and efficiently for planning integrated programs through the use of remote sensing.

The current research is performed in the context of the CAMELEO project, which aims to include monitoring of fluctuation in land surface conditions through earth observations.

Location of Study Area and Environmental Setting

The study area is located along the northern coast of Egypt limited by latitudes 30° 44' N to 30° 49' N and longitudes 29° 00' to 29° 28' E. It is bordered from the east by El-Hammam town and from the west by El-Alamein town (Fig. 1). The area is composed of sedimentary rocks that belong to the Tertiary and Quaternary ages. The strata, from the seacoast to the Libyan plateau, are formed of a calcareous formation of Pliocene and Pleistocene ages, but covered by recent aeolian and fluvial sediment

The presence of alternative ridges and depressions running parallel to the coast in an east-west orientation characterize the coastal plain of the study area. The ridges are formed of limestone with a hard-crystallized crust and vary in altitude and lithological features according to age. The most prominent ridges are the coastal, Abu-Sir and Gebel Mariout ridges (Ayyad and El-Ghareeb, 1984).

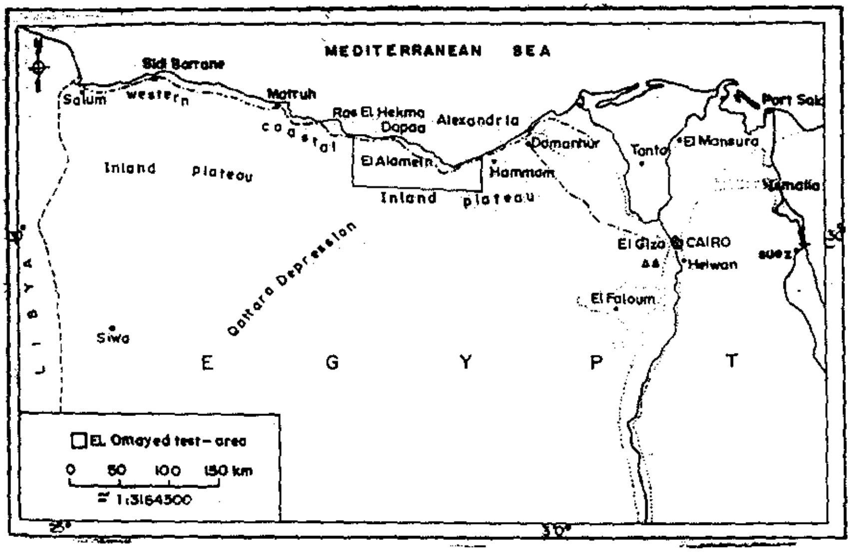

Fig. 1. Location map of study area.

The Abu-Sir ridge is separated from the coastal one by a depression having a mean surface elevation of 5 m above sea level and a width that varies between 300 meter and 1 km. It is filled with calcareous formation, highly saline in some places. The depression between Abu-Sir and Gebel Mariout ridges is occupied by the Mallahat Mariout depression. It has a width varying between 2 to 5 km. with surface mostly below sea level. The area is mainly filled with brackish water and saline calcareous deposits (El-Gabaly *et al.*, 1968). Gypsum crystals and organic mottles are observed near the water table forming a glued layer of olive grey colour (FAO, 1970).

Material and Methods

Several stretching processes were applied to the SPOT images sub-scenes of 1988 and 1997. These were used for the visual interpretation as guides for the fieldwork. The histogram equalization stretching process resulted in the maximum contrast between features of the two sub-scenes. False color composites (FCCs) of the two enhanced sub-scenes were created using the combination of bands 3,2,1 rendered in red, green and blue respectively. Unsupervised classification was applied on both images.

Field visits were based on the results of the preliminary analysis of the satellite images. It aimed at recognizing different soil and vegetation conditions. A number of 65 observation sites were studied, soil pits were investigated and samples were collected for laboratory analysis. Also, field radiometric measurements were performed to define the spectral characteristics of soil surfaces and land cover. Laboratory analysis of soil samples was performed to characterize properties of the soil associations.

The results of the field investigation and laboratory analysis fed back the image interpretation to elaborate soil conditions map. Cross tabulation, as a change detection technique, was applied on the two SPOT sub-scenes (1988 and 1997) covering El-Omayed observatory area. The chosen area has long historical data records, through ROSELT network.

Results and Discussions

Satellite image processing

Concerning the unsupervised classification of SPOT image of 1988 and 1997, it was possible to obtain a number of 28 classes, each has its spectral characteristics. The regrouping of the classes on basis of ground truth data and the system function of image alarm resulted in defining a number of 11 classes (Fig. 2). It was found that both class 1 and class 2 are mostly related to the "Deep Water", although the signature of the two classes was not identical. Classes 3 and 4 indicate the "Shallow Water" as they are extension of the previous class on the shoreline. The signature characteristic of class 5 is near to the signature of proposed shallow water, and is located in the inland near to the coast. Thus, "Wet Land" is assigned to class number 5. The "Sabkha" areas are located around the proposed wetlands near to the coast could be presented by class 6. Both classes 7 and 8, which are located along Alexandria-Matrouh road and the coast, are mostly related to the "Limestone and sand beaches". Due to the strong interference between the vegetation and bare soil pixels, it was not possible to differentiate between the bare soil and vegetation. Thus classes 9 and 10 are representing a combined class including both and have the name "Bare Soil & Vegetation. The interpretation was supported by results of previous studies carried out by Ayyad and Le Floch (1983) and El-Kanany (1995). The results gave a clue to build a reflection database for different soils and vegetation types in the study area.

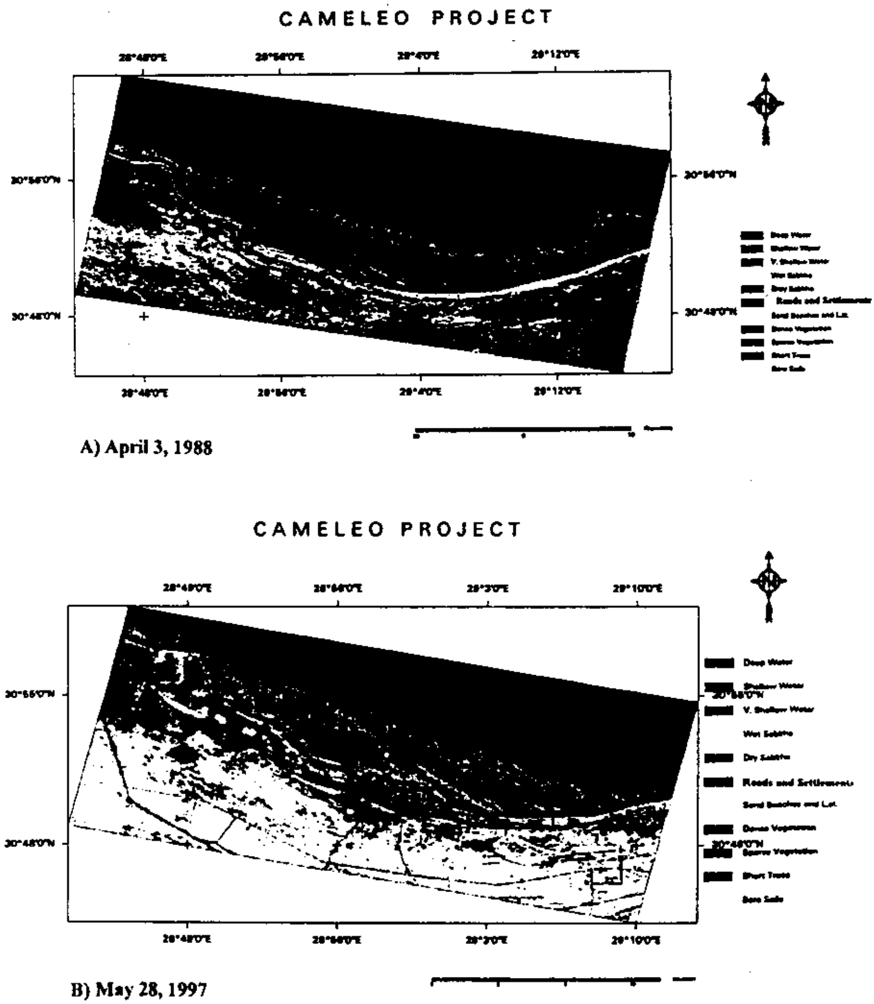

Fig. 2. Unsupervised classified SPOT images of study area.

Field studies and mapping of soil conditions

It was possible to identify five soil types (Fig. 3) as follows according to their salinity and depth;

1- Non to slightly saline (FC< 4ds/m), deep soils.

2- Non to slightly saline, moderately deep to shallow soils.

3- Moderately saline (EC = 4-8 ds/m), deep soils.

4- Moderately saline shallow soils

5- Highly saline soils (EC> 8 ds/m)

The non to slightly saline deep soils (Table 1-A) are characterized by a soil depth more than 100 cm and a texture class ranging from sand to sandy loam. The EC of soil past range from 0.15 to 3.4 ds/m, and the CEC from 1 to 12.5 meq/100 g soil. The calcium carbonate content ranges between 18.90 to 93.4% and the organic matter is 0.08 to 0.41%.

The non to slightly saline, moderately deep to shallow soils (Table 1-B) are characterized by a soil depth of 15 to 60 cm and a texture class ranging from sandy loam to loamy sand. The EC values range from 0.35 to 2.80 ds/m. The calcium carbonate content is rather high (29.25-75.0%) and the organic matter content ranges between 0.10 to 0.30%.

The moderately saline deep soils (Table 1-C) are characterized by a soil depth more than 100 cm and loamy sand and sandy loam soil texture. The EC values range from 4.13 to 8.0 ds/m and the CEC ranges between 4.1 to 13.50 meq/100 g soil. The calcium carbonate content is 26.8 to 80.3% and the organic matter ranges between 0.09 to 0.18%.

The moderately saline shallow soils (Table 1 -D) are characterized by a soil depth of 20 to 60 cm and sandy loam to loamy sand soil texture. The EC values range from 4.10 to 6.37 ds/m and CEC values from 2.8 to 21.8 meq/100 g soil. The calcium carbonate content ranges between 39.4 to 91.4% and the organic matter ranges between 0.09 to 0.24%.

The highly saline soils (Table 1-E) are characterized by a soil depth of 80 to 140 cm and sandy loam to loamy sand soil texture. The water table, in most cases, is found at 100 cm depth. The EC of the soils is high (> 8 ds/m), except

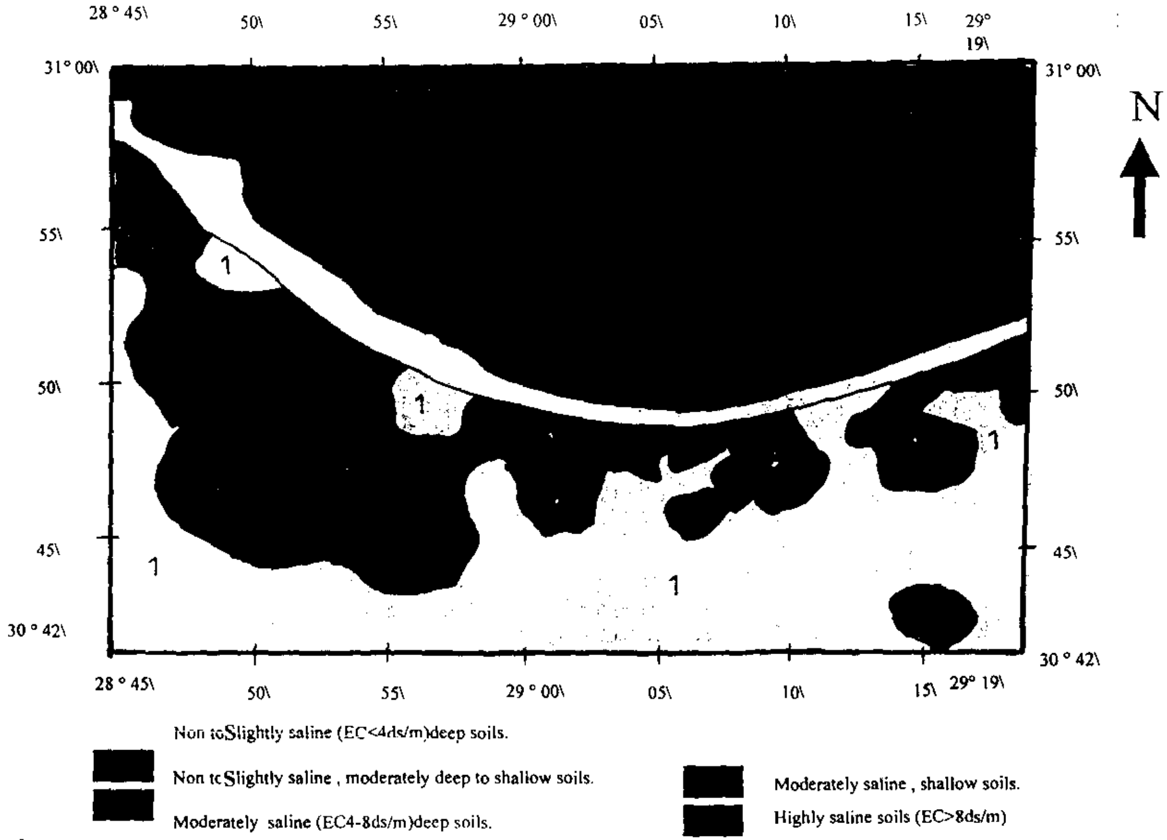

Fig. 3. Soil conditions map of a part of the north western coast, based on FFC of SPOT-XS< 1997.

TABLE 1. Physico-chemical properties of some soil profiles representing different soil units.

Soil Units *	Profile No. Depth	pH	EC dS/m	$CaCO_3$ (%)	Cations meq/l				Anions meq/l				O.M (%)	CEC meq/100 g soil	Particle size distribution			Texture
					Ca^{++}	Mg^{+}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}			Sand (%)	Silt (%)	Clay (%)	
A	2 (0-25)	8.35	0.92	33.10	7.00	3.00	0.85	0.20	0.00	0.80	1.50	8.75	0.16	7.20	80.00	11.00	9.00	Loamy Sand
	(25-100)	8.73	0.24	47.30	1.00	0.70	0.72	0.12	0.00	0.70	1.30	0.54	0.15	7.10	79.50	13.10	7.40	Loamy Sand
A	16 (0-50)	9.35	0.40	53.60	2.30	1.40	1.12	0.13	0.00	1.30	2.10	1.55	0.10	6.20	91.00	1.00	8.00	Sand
	(50-105)	9.46	0.35	47.30	2.00	1.10	1.10	0.11	0.00	1.50	1.90	0.91	0.07	6.00	80.10	8.80	11.10	Sandy Loam
	(105-150)	9.30	1.10	45.70	7.50	4.00	1.35	0.20	0.15	1.90	8.20	2.80	0.07	12.50	76.20	13.10	10.70	Sandy Loam
B	40 (0-15)	7.80	0.62	34.72	1.40	3.40	0.50	0.2	0.05	9.60	2.00	0.30	0.30	1.90	73.90	19.80	6.30	Sandy Loam
	(15-45)	7.82	0.51	42.25	1.00	4.40	0.20	0.20	0.00	9.00	1.50	0.85	0.12	1.20	80.10	10.70	9.20	Sandy Loam
	(45-60)	7.73	0.50	46.56	1.20	7.60	0.30	0.10	0.00	3.40	2.50	5.60	0.23	1.50	80.20	12.30	7.50	Sandy Loam
B	23 (0-15)	9.01	0.70	42.50	1.80	0.85	4.40	0.16	0.00	0.80	5.00	1.41	0.19	8.70	79.90	14.20	5.90	Loamy Sand
	(15-30)	9.97	0.35	61.40	0.85	0.40	2.50	0.20	0.00	0.500	1.50	1.95	0.10	9.90	68.90	24.20	6.90	Sandy Loam
C	7 (0-25)	8.58	7.90	33.10	18.00	6.00	6.75	0.43	0.00	2.80	6.00	22.18	0.13	4.20	76.50	14.40	9.10	Sandy Loam
	(25-50)	8.62	5.71	39.90	16.00	7.00	6.00	0.38	0.00	2.50	14.50	13.98	0.12	4.10	80.20	15.10	4.70	Loamy sand
	(50-110)	8.71	4.38	36.20	30.00	18.00	35.60	2.26	0.10	2.00	79.00	4.76	0.08	6.30	72.80	24.10	3.10	Sandy Loam
C	10 (0-30)	8.61	0.60	47.30	2.00	1.10	3.50	0.25	0.00	1.60	3.70	1.55	0.14	6.70	73.00	22.00	5.00	Sandy Loam
	(30-110)	8.87	7.00	69.30	26.40	16.40	32.66	1.95	0.95	3.80	58.60	14.06	0.10	6.50	76.80	16.00	7.20	Sandy Loam
	(110-150)	8.94	6.00	66.20	25.10	11.80	29.15	1.80	0.80	3.50	52.00	11.50	0.17	8.20	78.00	12.50	9.50	Sandy Loam
D	11 (0-25)	8.57	6.00	39.40	27.80	12.90	31.60	2.10	0.80	3.50	57.50	12.60	0.17	7.40	70.90	18.00	11.10	Sandy Loam
	11 (25-50)	8.55	4.10	91.40	16.70	8.70	19.80	1.60	0.50	0.85	38.10	5.35	0.09	7.00	69.10	21.00	9.90	Sandy Loam
D	18 (0-20)	8.31	4.50	66.20	19.50	11.00	20.60	0.75	0.00	2.50	41.30	5.05	0.17	6.40	59.50	30.00	10.50	Sandy Loam
	12 (0-60)	8.94	2.60	36.20	16.00	6.00	6.50	0.33	0.00	1.60	10.00	17.23	0.17	7.30	80.20	15.10	4.70	Loamy Sand
E	12 (60-110)	8.35	30.00	45.70	29.00	12.00	275.0	1.49	0.50	3.50	298.0	21.49	0.14	7.00	76.90	18.40	4.70	Loamy Sand
	12 (110-130)	8.23	29.00	52.00	30.50	19.00	273.0	1.55	0.85	3.21	290.0	29.99	0.11	3.50	75.20	20.90	3.90	Loamy Sand
E	14 (0-25)	9.33	0.60	36.30	2.90	1.40	2.11	0.16	0.00	1.00	3.20	2.37	0.13	3.20	86.50	10.40	3.10	Sand
	(25-115)	7.90	22.00	47.30	66.40	43.80	121.0	1.54	0.00	3.20	210.0	19.54	0.11	3.70	74.90	20.10	5.00	Loamy Sand
	(115-140)	7.92	21.50	50.40	64.80	43.00	118.0	1.80	0.00	2.90	210.0	14.70	0.11	4.80	82.60	11.80	5.60	Loamy Sand

* (A) Non to slightly saline deep soils, (B) Non to slightly saline, moderately deep to shallow soils, (C) Moderately saline deep soils, (D) Moderately saline shallow soils, (E) Highly saline soils.

in few surface layers is low (<4ds/m). The CEC values range from 2.2 to 10.2 meq/100 g soil. The calcium carbonate content is 11 to 55.1 and organic matter ranges between 0.10 to 0.17%.

The non-saline depressions and the northern gentle slopes are exhibited by the growing individual plant species. The normalized density of vegetation index (NDVI), based on SPOT-XS of 1997, proved that these areas have a relatively low land cover percentages (<20%). Such areas include overgrazed grassland as indicated by numerous features (excessive trampling, dung and poor growth of herbs and browsing of woody plants).

Field radiometric measurements for such soil type indicate a high reflection, especially in wavelength range over 800 nm. Different objects in the site have their particular reflection (Fig. 4). The dominant land degradation processes in these areas include vegetation degradation and wind erosion.

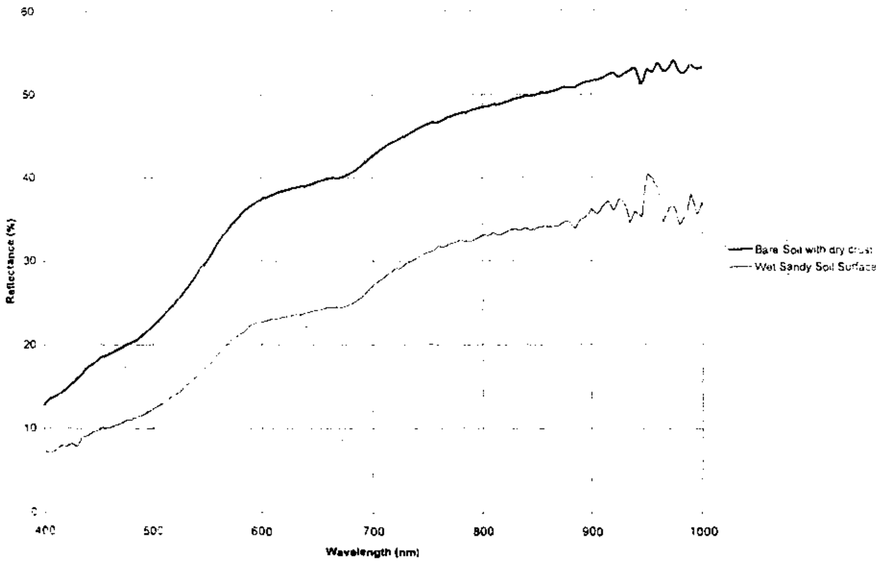

Fig. 4. Field radiometric measurements of Non to Slightly saline soils (site No. 2)

The moderate and high saline soils exist in the northern saline depressions. These are associated with short individual shrubs (average high less than 50 cm), while having a relatively high land cover percentage (average 25%). The radiometric measurements at site 9 (Fig. 5) represent the salt affected soils, with surface salt crusts, and growing halophytes. It is noticed that the salt affected soils, with surface salt crusts are characterized by high reflection compared with other surrounding land cover types. Such soils and their surroundings are exposed to problems of salinity, alkalinity and water logging.

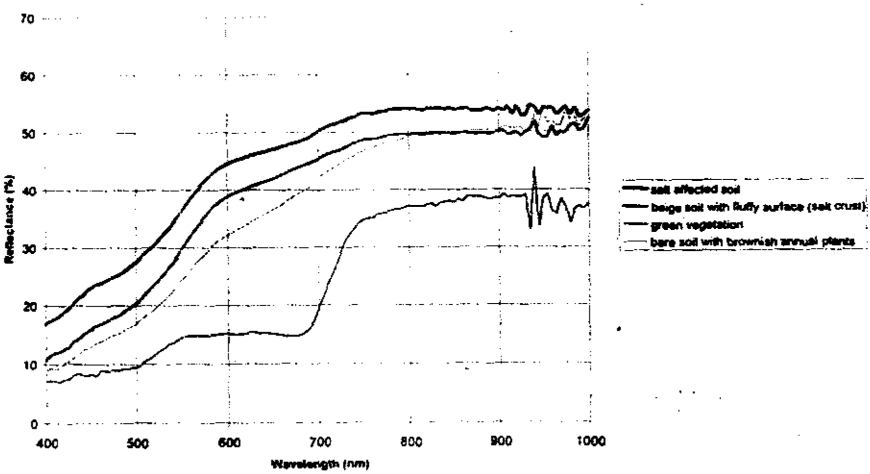

Fig. 5. Field radiometric measurements of the salt affected soils (site No 9).

Change detection of the land use/land cover

Application of change detection technique of land use and land cover classes, deduced from the SPOT images of 1988 and 1997, revealed that the area exhibited by Halophytes has increased from 10.47 to 14.10 km^2 (Table 2). The areas exhibited by short individual dense plant species (Shrubs 1- Fig. 6) have increased from 3.96 km^2 in 1988 to 16.18 km^2 in 1997. This change occurred mostly on the account of plant species that grow as tall individuals and in low land cover percentage (Shrubs 2). That means that the vegetation areas weakly influenced by man are replaced by overgrazed grassland, which is indicated by numerous features (excessive trampling, dung, and poor growth of herbs and browsing of woody plants). This type of vegetation cover is generally common in many of the areas within the non-saline depressions and northern gentle slopes of highland.

Classes	Shrubs (1)
Unclassified	0.00
Deep Water	0.00
Shallow Water	0.00
Halophytes	0.41
Shrubs(1)	0.80
Shrubs(2)	1.92
Fig Trees	0.07
Degraded Lands	0.65
Settlements	0.04
Beach sand & Limestone	0.02
Lake Water	0.01
Gardens	0.01
Digging Output	0.02
Total	3.96

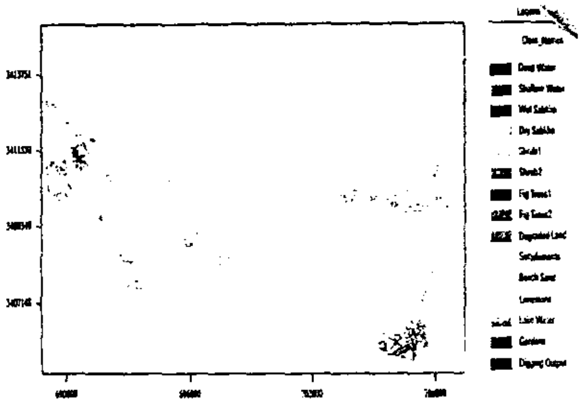

Fig. 6. Classes changed from "Shrubs 1" during the period 1988 to 1997.

The coverage of the sand beaches and limestone exposures (Fig. 7) decreased from 13.15 km^2 in 1988 to 7.31 km^2 in 1997. This change occurred mainly into the classes of "Settlements, as resort houses, and in door gardens" (2.7 km^2), "Halophytes" (2.34 km^2) and "Burrowing (1.1 km^2). That explains the excessive erection of resort houses on the northwestern coast and their consequences on the habitats. New classes appeared in the images of 1997, as Lake Water, digging outputs and indoor gardens. These features occurred as a result of resort housing infrastructure development and the introduction of an under structure irrigation canal.

Conclusion

It is possible to conclude that the change in land use/land cover may indicate land degradation phenomena. The study area is subjected to land degradation processes, most are man induced ones. The progressive erection of resort houses along the coast resulted in disappearance of sand beach mounds and associated habitats. Short individual shrubs replaced and indicate saline soil proper. Also, common limestone artificial quarries were created along the coastal road due to

Classes	Beach sand and limestone exposures
Unclassified	0
Deep Water	0
Shallow Water	0.14
Halophytes	2.34
Shrubs(1)	0.17
Shrubs(2)	0.11
Fig Trees	0.14
Degraded Lands	0.58
Settlements	1.42
Beach sand & Limestone	5.61
Lake Water	0.22
Gardens	1.32
Digging Output	1.11
Total	13.15

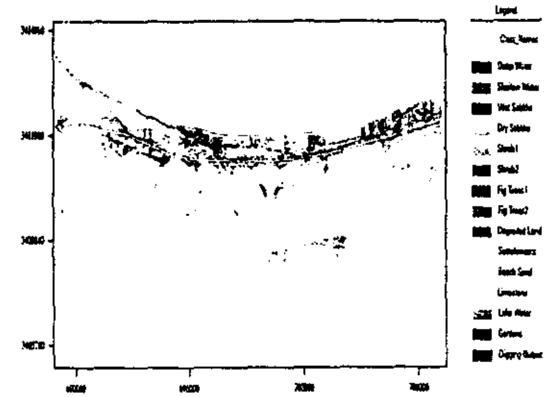

Fig. 7. Classes changed from "Beach sand & Limestone exposures" during the period 1988 to 1997.

TABLE 2. Cross tabulation between land use/ land cover classes in 1988 (columns) and 1997 (rows), based on classifying SPOT images.

Classes	Unclassified	Deep Water	Shallow Water	Halophytes	Shrubs (1)	Shrubs (2)	Fig Trees	Degraded Lands	Settlements	Beache sand and limestone	Total
Unclassified	41.28	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0	41.28
Deep Water	0.04	32.39	10.59	0	0.00	0.00	0.00	0.00	0.00	0	43.12
Shallow Water	0.00	0.78	8.52	0.18	0.00	0.00	0.00	0.00	0.02	0.14	9.64
Halophytes	0.02	0	0.12	3.43	0.41	4.03	0.56	2.77	0.43	2.34	14.1
Shrubs(1)	0.03	0.00	0.00	2.96	0.80	8.01	0.12	4.08	0.01	0.17	16.18
Shrubs(2)	0.17	0.00	0.00	0.66	1.92	34.56	0.12	5.34	0.00	0.11	42.89
Fig Trees	0.00	0.00	0.00	0.29	0.07	0.63	[illegible]	0.61	0.00	0.14	1.76
Degraded Lands	0.07	0.00	0.00	0.28	0.65	14.69	0.02	3.99	0.01	0.58	20.28
Settlements	0.00	0.00	0.07	0.41	0.04	0.37	0.11	0.38	0.56	1.42	3.32
Sand Beaches & Limestone	0.01	0	0.3	0.56	0.02	0.11	0.09	0.47	0.14	5.61	7.31
Lake Water	0.00	0.14	1.77	1.28	0.01	0.00	0.04	0.00	0.04	0.22	3.51
Gardens	0.00	0.00	0.02	0.29	0.01	0.21	0.01	0.28	0.26	1.32	2.40
Digging Output	0.00	0.00	0.01	0.12	0.02	0.38	0.01	0.36	0.04	1.11	2.05
Total	41.63	33.41	21.38	10.47	3.96	62.99	1.07	18.27	1.51	13.15	207.85

the use of its rocks in raising resort land levels. The exposed lower sediments caused negative effect on the vegetation cover percentage. Other degradation agents (*i.e.* wind erosion and seasonal water erosion) are provoked, where the soils in the non-saline depressions and gentle slopes are vulnerable to erosion. processes. Native economic plants (*i.e.* fig trees) have diminished and were replaced by served fig trees in the plateau and halophytic plants in the depressions.

Remote sensing has proved to be a satisfactory tool in surveying land use/land cover. Different remote sensing facilities may lead to useful information to understand the environmental conditions. Visual interpretation of satellite images may give a clue on density of vegetation and various land use patterns. The digital processing of satellite images can quantify the changes. The measurements of field radiometry define the spectral characteristics of the objects, which can be followed on the images as criteria for land degradation.

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ملاحظة وتقييم تجديد انحدار الأرض بطول الساحل الشمالي لمصر باستخدام صور الأقمار الصناعية المتعددة زمنيا

عبد الله جاد و م.أ. يحيى

المركز القومى للبحوث -الدقى - الجيزة و الهيئة لقومية لعلوم الفضاء والاستشعار عن بعد - القاهرة - مصر .

تقع منطقة الدراسة فى الساحل الشمالي للبحر المتوسط بمصر بين مدينة الحمام شرقا ومدينة العلمين غربا.

النمطقة الواقعه بين ساحل البحر الى النجد الليبي عبارة عن تكوين جيري من عصري البليوسين والبلستوسين ولكن مغطاه بالرواسب الحديثه .

الانشطة الرياضيه والنهرية تعيد عمل الرواسب والعواصف الجنوبية الدافئه المحمله بالاتربه تضر بالزراعة وتسبب فقدان ماء التربه من خلال تأثيرها على زيادة الرشح كما أن جميع النباتات للوقوف على نتاق واسع قد اعاقت بلاشك التطور الطبيعى للتربة والنمو .

يهدف البحث الحالي الى الكشف عن مؤثرات تجريد الارض من خلال استخدام تسهيلات الاستشعار عن بعد متعددة الطبيعة وصور الاقمار الصناعية المتعددة زمنيا.

تم تعزيز نافزتين من صور الاقمار الصناعية spot-Xs من سنة ١٩٨٨ و ١٩٩٧ رقميا وتم تصنيفها وتصحيحها هندسيا وتم تنفيز الفحص الحقلى على اساس التحليل الاولى للصور وتم استحداث اسلوب تصنيف Hypeird باستخدام كل من حقيقة الارض والطبقات الطيفية .

وقد تم عمل خريطة بالحالة الحالية للتربة بناء على صورة لعام ١٩٩٧ والفحص الحقلي وتم استبعاد خريطتين Spot-Xs معتمدتين للاستخدام الارضى والغلاف الأرضى لعامى ١٩٨٨- ١٩٩٧ واظهر تطبيق اسلوب الملاحظة المتغيرة على نظامى البيانات زيادة فى مساحة التربة الملحية و الفوق ملحية من عام ١٩٨٨ حتى ١٩٩٧ زادت مناطق النمو المميزة بالانواع النباتية النامية كافراد تثير على حساب مناطق النمو المميزة بالاصناف النباتية طويله الافراد ولقد حلت المحاجر الجيرية الصناعية وحدائق التين التى يتم المحافظة عليها بواسطة الممارسات الزراعية المتوسطة الى عالية المستوى محل الكثبان المكونات الأخدودية الأخرى .