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Integrating GIS and RS for Land Reclamation at Siwa Oasis

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THE AIM of the present study is to characterize the main soil units of an area covers approximately 8800 feddans, as an attempt to integrate a reclamation plane of Siwa Depression for sustainable agriculture development, using the integration of GIS/RS techniques. Digital Elevation Model (DEM) showed that the elevations varied between 13 m. B.S.L and 1 m. A.S.L. A window of Landsat7 ETM^+ (Enhanced Thematic Mapper) image that acquired in May 2002 was selected to represent the studied area. Twenty spectral classes were created using bands 4, 3, and 2 as RGB (Red, Green and Blue bands) throughout the unsupervised classification technique. This case study has demonstrated the usefulness of integrated model-image analysis-GIS approaches in successfully identifying soil mapping units. Seven soil mapping units were established using the most effective soil properties in the spatial distribution pattern of the studied area. These soil mapping unites are: (I) free shallow saline water (W), represents 7.45 % of the total area, (II) Halite rock (S), represents 7.25%, (III) Salty hardpan (Kersheif) (K), represents 61.26 %, (IV) Saline loamy sandy soil over white phosphorus (220 ppm) layer (H), represents 0.80%, (V) Deep saline sandy soil (Sd) represents 18.28 %, (VI). Moderately deep saline sandy soil (Sm) represents 1.60 % and (VII) Shallow strongly saline sandy soil(Ss), represents 3.36 %. The soil depth was limited by a highly saline water table. From the investigation of the studied area, a ditch drain and wind brake are needed to be installed at specific locations of (Sd), (Sm) and (Ss) soil units, as well as leaching the soil in order to remove the overloaded salts, two month before cultivation. This study illustrates that integration of remotely sensed data and GIS techniques are effective in order to provide information about the studied area characteristics.

Siwa depression is one of the many depressions of the Western Desert of Egypt. It occupies an area of about 2000 Km^2 within the northwestern part of the

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Western Desert. The depression is bounded by Marmarica Plateau that formed of carbonate marine rocks at its northern parts, and by the Great Sand Sea of the Western Desert of Egypt at its southern parts (Mohammad *et al*., 2004).

The soil of Siwa depression is generally saline due to several factors such as high evaporation, salinity of irrigation water, shallow water table and, inappropriate soil management practice; therefore selection of the most suitable area for agricultural activities is necessary (Balaba, 1992). AOAD (1977) has concluded that about 7000 hectar of Siwa soils are considered as cultivatable. The utilized area was 800 hacters in 1962, increased to 1360 hactars in 1977, to 2800 hactars in 1984 (Arar,1984).

Shatanawi (1991) summarized the processes of land reclamation of some areas in Siwa as: i) removing the surface 7-10 cm layer salt crust, called locally Kersheif; ii) turning the under laying soil layer and getting the lower layer to the top, in some cases rocks and salt remnants are removed then the new soil surface is mixed with sand and animal manure; iii) and finally digging drains and constructing the irrigation system before the cultivation processes.

Land cover is a fundamental parameter describing the Earth's surface. This parameter is a considerable variable that impacts on and links many parts of the human and physical environments (Foody, 2002).

Satellite remote sensing, in conjunction with geographic information systems, has been widely applied and been recognized as a powerful and effective tool in analyzing land cover/use categories (Ehlers *et al*., 1990; Harris & Ventura, 1995 and Weng, 2001). In this study remotely sensed data and GIS technologies are used to evaluate qualitatively and quantitatively land cover/use distribution. Obtained results were manipulated, visualized and analyzed, in Geographic Information System.

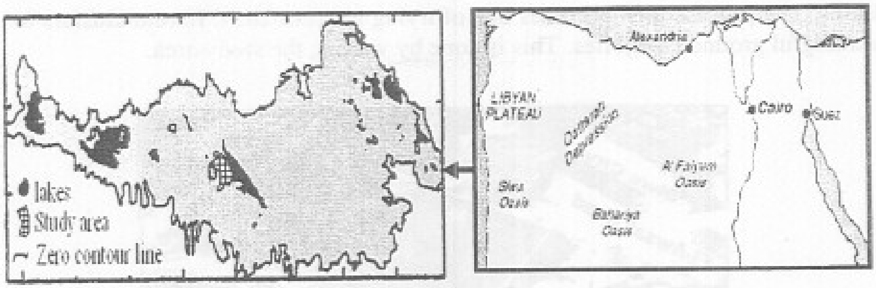
Modern information technology that link geographic information system (GIS) capabilities with remote sensing (RS) data contribute significantly in the assessment and management of the planned agricultural development (Zhou *et al.*, 1989 and Davis *et al.*, 1991).

The objectives of this study are to characterize the main soil units using the integration of GIS / RS techniques, as well as to propose a soil reclamation-scenario for the studied area at Siwa depression for sustainable agriculture development.

Material and Methods

Location

The studied area is located east of Siwa city. It lies approximately between latitudes 29 12' 42" and 29 8' 20" N, and longitudes 25 36 31′ and 25 39 12′ E. The studied area covers an approximately 10,000 feddans. The following map shows the site of the studied area at Siwa oasis.



Map. 1. Location of studied area.

Satellite image

A window of Landsat7 ETM+ (Enhanced Thematic Mapper) image acquired in May 2001 was selected to represent the studied area (Map2).

Image registration

Image registration is the first step to be carried out before proceeding to any further image processing. This step assigned coordinate systems to the image and linked it to its location on the ground. The ETM+ image was geometrically rectified to the digitized topographic maps using image-to-map procedure in ENVI 4.0 software (ENVI, 2003).

Resolution merge

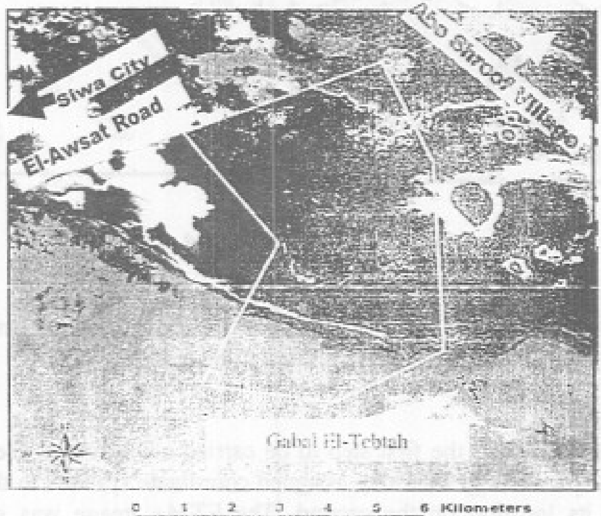
This process is used for imagery integration of different spatial resolutions (pixel size). Since higher resolution imagery is generally single band (ETM Panchromatic 15m data), while multispectral imagery generally has the lower resolutions (ETM 30m), this technique are often used to produce high resolution multispectral imagery. This improves the interpretability of the data by having high resolution information which is also in color. Resolution Merge offers three techniques: Multiplicative, Principal Components, and Brovey Transform (ERDAS, 2001).

Satellite image classification

Erdase imaging 8.5 was used to carry out the image classification. The following steps were used for image classification:

A- Subset of Study Area: This process cuts out (clip) the preferred study area from the larger image scene into a smaller more manageable file.

B-Unsupervised Classification: An unsupervised classification routine (CATEGORIZE) was used to create clusters of pixels with similar spectral characteristics in purpose of recognizing the main classes. Twenty spectral classes were created using bands 4, 3, and 2 as red-blue-green bands (RGB) to be input to the module. The obtained classes were regrouped into seven spectral classes. The process then becomes one of trying to relate the different clusters to meaningful ground categories. This is done by visiting the study area.



Map. 2. Satellite image (ETM$^+$ 2002) of the studied area.

Topographic maps

The study area is covered by four topographic map sheets at scale 1:50000. The ENVI software is used to convert the geographic coordinates (Lat-Long) system to Universal Transverse Mercator (UTM) coordinates (Easting-Northing) system.

Generation of DEM

DEM is defined as any digital representation of the continuous variation of relief over space (Burrough, 1986 by means of digitized contour lines of 1:50000 scaled topographic maps in every 10 m interval as well as spot heights, DEM of the study area was performed by using interpolation procedure. Contour Gridder extension was used to generate the Digital Elevation Model (DEM) within ArcView 3.2 environment (ESRI, 1999). DEM was analyzed to generate the degree of slope classes and Aspect.

Soil survey and sampling

By using the ETM+ image revised unsupervised classification, in addition to the topographic maps; the locations of the thirty four representative soil profiles were identified and dug according to variations among the spectral mapping units.

Laboratory analyses

Chemical and physical analyses were carried out according to Page *et al.* (1982).

Descriptive statistical parameters

Minimum, maximum, mean, standard deviation and coefficient of variance were calculated using SPSS software Ver. 12 (2003).

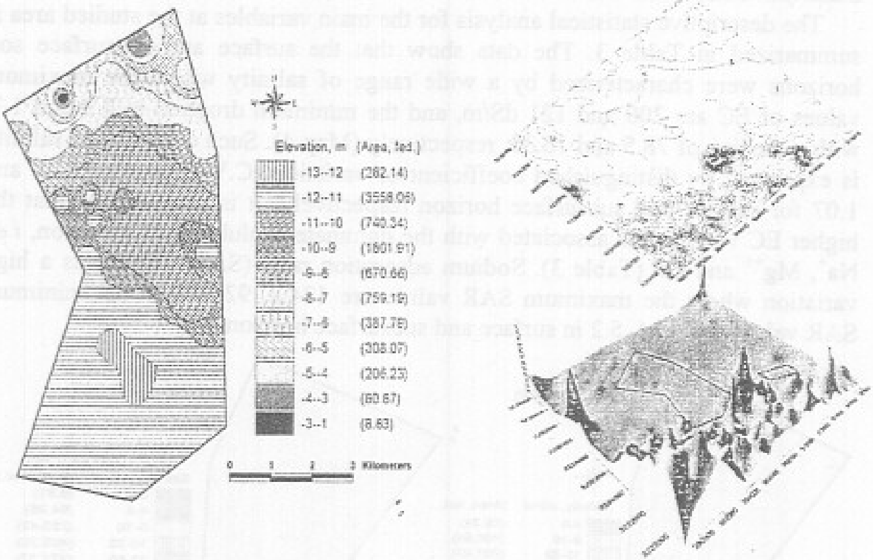
Building up digital georeference database

Data input process is the operation of entering the spatial and non-spatial data into GIS using ArcView software (ESRI, 1999). Each soil observation was geo-referenced using the Global Position Systems (GPS) and digitized. The different soil attributes were coded, and new fields were added to the profile database file in Arc/View software. Surface interpolate grid were done for soil salinity, Soil depth, $CaCO_3$ % using module Arc Scripts in ArcView 3.2.

Results and Discussions

Land surface analyses

Digital elevation model (DEM) of the studied area contributes to the storage of elevation data as digital map and 3-D, (Map 3). The most advantage of the GIS is the ability to process elevation data in a digital format, and obtains valuable information about the land surface; Carter (1988). DEM was obtained from the digital contour map, using the interpolation technique. The lowest elevation in the study area is -13 m A.S.L. and the highest one is 1 m, A.S.L.



Map. 3. Digital elevation model and three dimension of studied area.

The slope derived from the digital elevation model ranged from 0 % to 2 %. Data revealed that most of the study area is leveled to nearly leveled (Table 1).

TABLE 1. Areas and percentages of slope classes.

Class	Description	Area (fed.)	Area %
0 - 0.2 %	Level	4935.33	55.84
0.2 - 0.5%	Nearly level	2975.45	33.46
0.5 - 1%	Very gently slope	778.53	8.56
1 - 2 %	Gently sloping	114.35	1.22

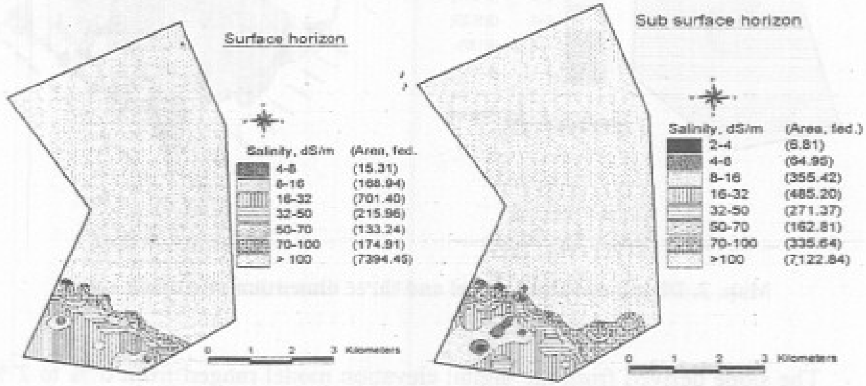
Aspect is presented in Table 2. The data indicated that the dominant slope directions are north and south which form the general trends in the studied area and constitute more than 77 %.

TABLE 2. Directions, areas and percentages of aspect classes.

Direction	Area (Fed.)	Percent %
North	,3240.93	36.81
East	1041.24	11.83
South	3570.38	40.56
West	950.77	10.80

Descriptive statistical estimates

The descriptive statistical analysis for the main variables at the studied area is summarized in Table 3. The data show that the surface and subsurface soil horizons were characterized by a wide range of salinity where the maximum values of EC are 200 and 121 dS/m, and the minimum dropped to 4.9 and 1.7, with a median of 78.5 and 16.35, respectively (Map 4). Such over-spread salinity is expressed by distinguished coefficient of variation (C.V.) value of 0.72 and 1.07 for surface and subsurface horizon respectively. It is also noticed that the higher EC variation is associated with the dominated soluble ions variation, *i.e.*, Na^{+}, Mg^{++} and Cl^{-} (Table 3). Sodium adsorption ratio (SAR) represents a high variation where the maximum SAR values are 134.2, 92.74 and the minimum SAR values are 6.14, 5.2 in surface and subsurface horizon.

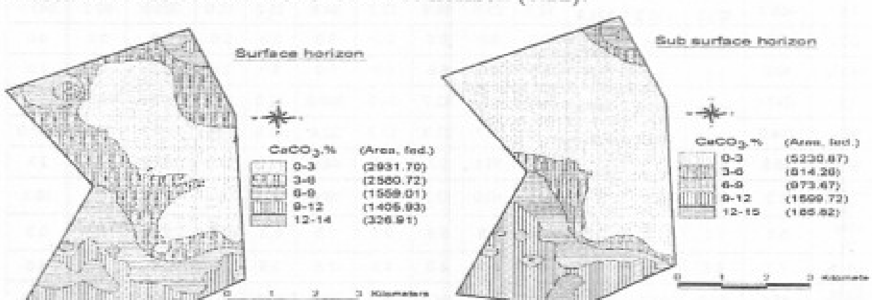


Map. 4. Distribution of soil salinity dS/m in studied area.

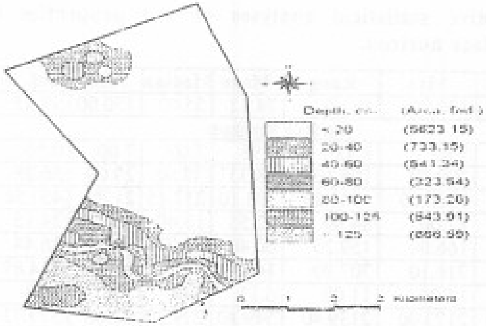
TABLE 3. Descriptive statistical analyses of soil properties for surface and subsurface horizon.

Soil properties	Min.	Max.	Range	Mean	Median	Mode	Std. Dev.	Variance	C.V.
Depth, cm	5.00	150.00	145.00	74.12	55.00	150.00	59.32	3518.89	0.80
Surface horizon									
pH	5.99	7.82	1.83	6.98	7.00	7.00	0.56	0.31	0.08
EC, dS/m	4.90	200.00	195.10	78.33	78.50	29.00	56.28	3167.60	0.72
Na, meq/l	21.80	1965.00	1943.20	393.10	217.15	21.80	451.56	203902.59	1.15
K, meq/l	2.20	87.00	84.80	22.55	13.40	8.90	24.15	583.33	1.07
Ca, meq/l	6.80	166.00	159.20	60.40	52.90	6.80	36.44	1327.52	0.60
Mg, meq/l	8.20	716.10	707.90	146.92	41.20	8.20	214.89	46179.23	1.46
HCO_3, meq/l	3.00	14.00	11.00	6.13	5.00	5.00	2.31	5.33	0.38
Cl, meq/l	33.60	2173.00	2139.40	549.80	279.30	33.60	579.73	336081.91	1.05
SO_4, meq/l	4.30	325.70	321.40	81.16	34.45	4.30	99.02	9804.69	1.22
SAR	6.14	134.20	128.06	36.43	31.69	6.14	26.43	698.78	0.73
$CaCO_3$, %	0.27	13.65	13.37	7.75	9.37	10.92	4.70	22.09	0.61
Clay, %	0.00	7.50	7.50	1.86	1.75	0.25	1.92	3.68	1.03
Silt, %	2.00	9.26	7.25	5.13	4.38	3.75	1.96	3.85	0.38
Sand, %	83.74	97.50	13.76	93.01	93.75	96.00	3.49	12.19	0.04
Subsurface horizon									
pH	6.23	7.92	1.69	7.44	7.65	7.65	0.49	0.24	0.07
EC, dS/m	1.70	121.00	119.30	29.82	16.35	20.00	31.80	1011.26	1.07
Na, meq/l	9.40	889.00	879.60	157.57	107.20	9.40	200.18	40070.97	1.27
K, meq/l	0.60	17.20	16.60	5.94	5.10	5.10	4.31	18.56	0.72
Ca, meq/l	2.00	112.40	110.40	36.09	24.40	2.00	28.11	790.01	0.78
Mg, meq/l	3.90	100.30	96.40	34.56	25.60	30.20	30.00	900.27	0.87
HCO_3, meq/l	3.00	6.00	3.00	4.58	5.00	5.00	0.96	0.92	0.21
Cl, meq/l	11.50	981.60	970.10	198.88	136.30	11.50	222.96	49710.32	1.12
SO_4, meq/l	0.50	91.30	90.80	27.31	22.00	0.50	24.86	617.89	0.91
SAR	5.02	92.74	87.71	23.44	21.97	5.02	20.09	403.61	0.86
$CaCO_3$, %	6.55	15.46	8.91	10.53	10.69	7.28	2.34	5.46	0.22
Clay, %	0.00	2.50	2.50	0.68	0.25	0.25	0.67	0.45	0.98
Silt, %	3.75	10.01	6.25	4.26	4.00	3.75	1.32	1.74	0.31
Sand, %	88.74	96.25	7.50	95.05	95.75	96.00	1.63	2.66	0.02

The data also showed that water table depth represents a high variability, where the maximum depth is 150 cm and the minimum is 5 cm (Map 6) with a median 55 cm. The C.V. value for water table depth was 0.8. The data illustrate the variations of calcium carbonate content in the surface and subsurface horizons, were the maximum values are 13.65 and 15.46, and the minimum values are 0.27 and 6.55 (Map 5) with a median of 9.37 and 10.69 for surface and sub surface, respectively. The C.V value is highly variable (0.61) for surface horizon and less variable for subsurface horizon (0.22).



Map. 5. Distribution of calcium carbonate content in the studied area.



Map. 6. Distribution of water table depth in the studied area.

Soil mapping units

The soil of the studied area could be classified into seven soil mapping units according to the variations of the different soil characteristics, as shown in the following Table 4 and 5, Map 7 and Fig 1.

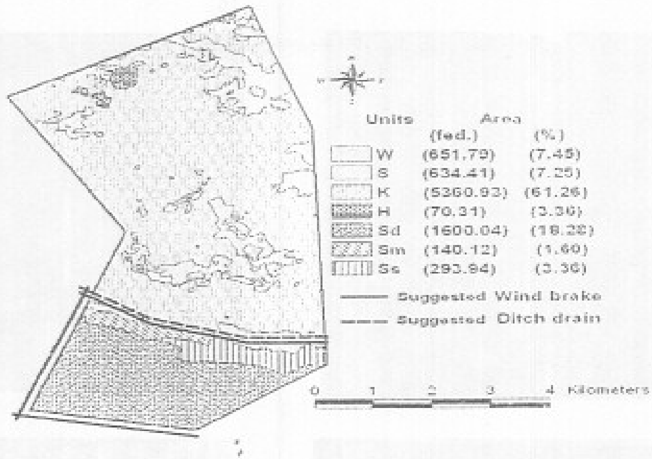
TABLE 4. Soil units descriptive.

W	Free shallow saline water
S	Halite rock
K	Salty hardpan (Kersheif).
H	Saline loamy sandy soil over white phosphorus (220 ppm) layer
Sd	Deep saline sandy soil
Sm	Moderately deep* saline sandy soil
Ss	Shallow*, strongly saline, sandy soil

* Profile depth is limited by saline water table.

TABLE 5. Soil chemical and physical analysis of soil units.

Units	K	H			Sd				Sm			Ss		
Depth, cm	0-5	0-20	20-40	40-60	0-40	40-80	80-110	110-150	0-25	25-50	50-75	0-10	10-35	35-50
pH	6.9	6.8	6.2	5.4	7.5	7.8	7.8	7.7	7.6	7.7	7.1	6.6	7.4	7.8
EC, dS/m	129.0	108.0	121.0	79.0	4.9	12.2	6.8	5.7	40.0	8.6	8.2	200.0	37.5	98.0
Na	921.0	593.9	695.7	336.5	21.8	58.8	25.5	25.0	304.2	48.6	46.5	1965.0	227.8	50.2
K	51.0	20.5	41.0	30.8	3.2	7.2	4.5	3.5	19.9	2.6	3.7	68.4	17.2	33.4
Ca	83.0	57.2	275.3	210.4	12.5	33.4	21.2	16.5	58.4	22.6	20.8	102.8	63.0	107.0
Mg	465.0	502.2	400.3	321.8	12.7	25.6	18.8	12.2	34.8	10.2	10.0	326.0	92.2	543.1
CO_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCO_3	10.0	7.0	9.0	3.0	5.0	6.0	5.0	5.0	5.0	3.0	3.0	6.0	4.0	7.0
Cl	1247.0	998.4	820.0	793.4	33.6	90.3	43.7	39.0	380.0	72.0	70.0	2173.0	363.3	989.7
SO_4	214.0	168.0	586.3	103.1	11.6	28.7	21.3	13.2	32.4	15.0	13.0	283.2	32.9	237.0
SAR	55.6	36.5	37.9	20.6	6.1	10.8	5.7	6.6	44.6	11.0	11.0	134.2	25.9	2.8
$CaCO_3$, %	1.3	13.2	9.1	0.1	10.9	10.9	12.7	9.1	10.9	15.5	13.6	10.0	6.5	10.5
Clay, %	5.0	7.5	1.3	2.5	1.8	1.3	0.0	0.3	2.5	0.3	0.3	2.5	0.3	0.3
Silt, %	7.5	8.8	5.0	6.3	4.5	4.0	4.0	4.0	2.5	3.8	3.8	2.5	3.8	3.8
Sand, %	87.5	83.7	93.7	91.2	93.7	94.7	96.0	95.7	95.0	90.0	96.0	95.0	96.0	96.0
Texture	LS	LS	S	S	S	S	S	S	S	S	S	S	S	S



Map. 7. Soil mapping units of the studied area.

Conclusion

This study demonstrates the usefulness of GIS for terrain parameter analysis and the effectiveness of GIS and remote sensing integration for monitoring and mapping soil characteristics and potential soil unites for land reclamation.

From the investigation of the studied area, it is obvious that the soil mapping unit Deep Saline Sandy Soil (Sd) should have the most priorities for land reclamation followed by Moderately Deep Saline Sandy Soil (Sm) and Shallow Strongly Saline Sandy Soil (Ss). On the other hand, the soil mapping units: Saline Loamy Sandy Soil (H), Halite Rock (S), Salty Hardpan (Kersheif) (K), and Free Shallow Saline Water (W) are considered unsuitable for agricultural purpose.

In order to prevent highly saline water from invading soils, a ditch drain is proposed to be dug, to separate the saline water from the sandy soil in the south. A cultivated windbreak belt is also needed to be grown to prevent the saline dust and vapour from depositing on the soil surface, and consequently it will increase the salinity problem. Moreover, leaching of overloaded salts from the soil should be carried out through irrigation systems, at least two month before cultivating the desired crop.

The outcome of this type of study represents a valuable resource for decision makers to guard against land acquisition and degradation, and for future development projects in the study area in Siwa Depression.

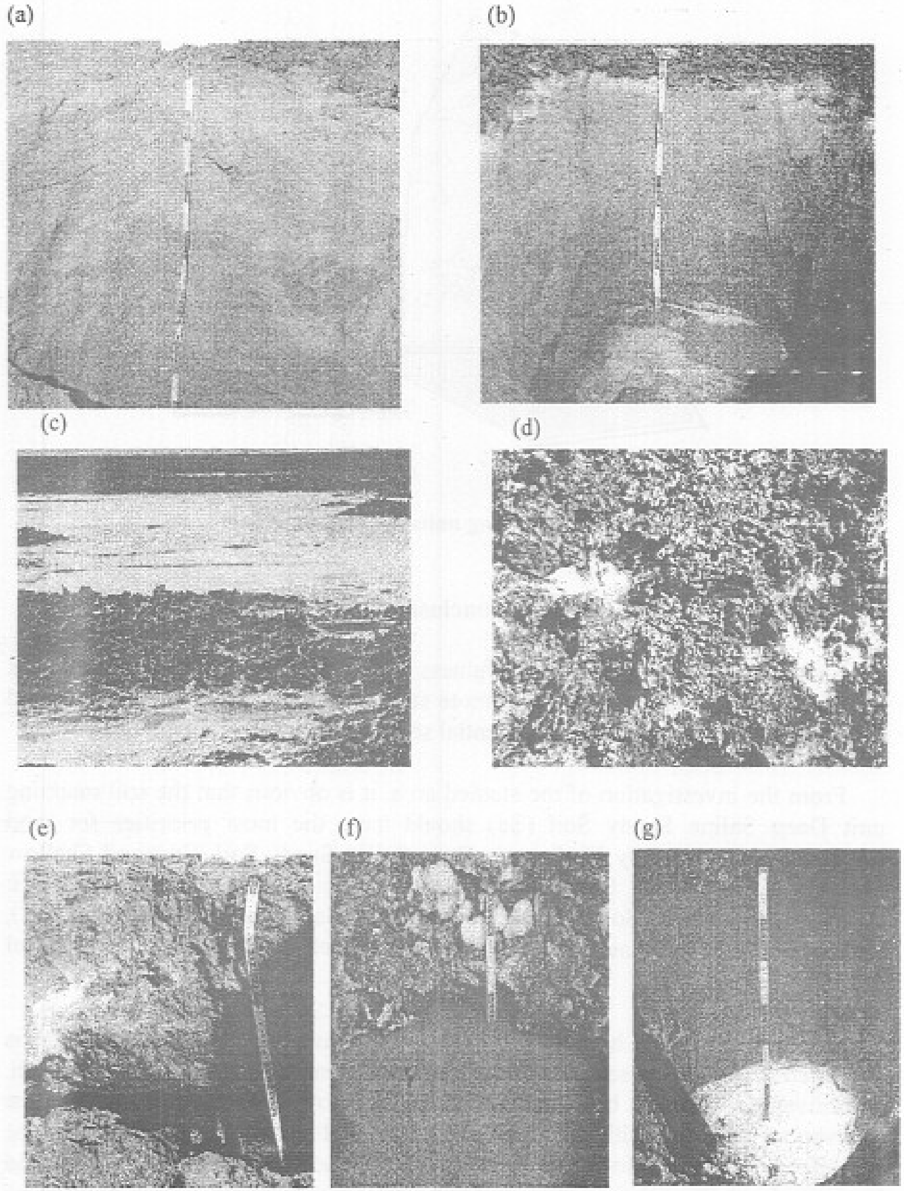


Fig . 1.Soil mapping unites of the studied area:
(a) Deep saline sandy soil (Sd).
(b) Moderately deep saline sandy soil (Sm).
(c) Free shallow saline water (W).
(d) Salty hardpan (Kersheif) (K).
(e) Halite rock (S).
(f) Shallow strongly saline sandy soil (Ss).
(g) Saline loamy sandy soil over white phosphorus (220 ppm) layer (H).

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تكامل نظم المعلومات الجغرافية والاستشعار عن بعد لاستصلاح الأراضى بمنخفض سيوة

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يهدف هذا البحث الى توصيف الوحدات الأرضية السائدة بمنطقة الدراسة والتى تقع شرق منخفض سيوة و تغطى مساحة ٨٨٠٠ فدان، وكذلك تحيد أنسب المناطق لأولوية الاستصلاح والاستزراع وذلك من خلال التكامل بين تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد. وقد أوضحت النتائج من خلال نموذج الارتفاعات الرقمية DEM أن الارتفاعات فى المنطقة المدروسة تراوحت من ١٣ متر تحت سطح البحر الى ١ متر فوق سطح البحر. وتم تصنيف المنطقة المدروسة الى سبع وحدات أرضية وذلك بناء على التغيرات فى خواص التربة والتغيرات فى صورة القمر الصناعى +Landsat7 ETM الملتقطة فى مايو ٢٠٠٢. الوحدات الارضية السائدة فى منطقة الدراسة هى: مناطق غدقة شديدة الملوحة (W)، مناطق تتميز بوجود طبقة متصلبة من صخر الهاليت والقريبة جدا من السطح (S)، مناطق تتميز بانتشار طبقة رقيقة من الاملاح الهشة (كورشيف) على السطح (K)، مناطق تتميز بالطبقة السطحية ذات الملوحة المرتفعة والقوام السلتى الرملى والممتدة فوق طبقة بيضاء ذات محتوى عالى من الفسفور (٢٢٠ جزء فى المليون) (H)، مناطق تتميز بالملوحة المرتفعة والقوام الرملى والقطاع الارضى العميق (Sd) ، مناطق تتميز بالملوحة المرتفعة والقوام الرملى والقطاع الارضى غيرالعميق (Sm)، مناطق تتميز بالملوحة المرتفعة جدا والقوام الرملى والقطاع الارضى الضحل لارتفاع مستوى الماء الارضى (Ss)، حيث تمثل هذه الوحدات ٧,٤٥٪، ٧,٢٥٪، ٦١,٢٦٪، ٠,٨٪، ١٨,٢٨٪، ١,٦٪، ٣,٣٦٪ على التوالى من المساحة المدروسة.

وأظهرت النتائج أن الوحدات الأرضية Sd، Sm، Ss هى التى تحظى بأولوية الاستصلاح على الترتيب، وينصح بانشاء مصرف صرف فى مناطق معينة على امتداد الوحدات الارضية الثلاث سالفة الذكر وذلك لخفض مستوى الماء الارضى ومنع حدوث عملية التملح، كذلك ينصح باقامة أو زراعة مصدات للرياح على الجهات الجنوبية والغربية من منطقة الدراسة وذلك لكسر حدة الرياح ومن ثم وقف الرمال المتحركة أو السافية.