Journal of Applied Sciences Research, 9(11): 5609-5618, 2013
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Use of geomatics for mapping soil resources: A case study in some areas, west Nile Valley, Egypt.

[1]M.A. Elsemary, [1]R.R. Ali, [2]Kh. M. Darwish and [1]M.A. Wahab

[1]Soils and Water Use Dept., National Research Centre (NRC) Egypt.
[2]Land & Water Tech. Dept., Arid Land Research Inst., City of Scientific Research and Technological Applications, Borg El-Arab, Alex., Egypt.

ABSTRACT

Land capability assessment for agriculture aims to predict the forthcoming situations after development has taken place. It is needed to predict the benefits to farmers and the general economy and whether these will be sustained. Thus, providing integrated and accurate information about soil resources is a must, especially with the accelerated progress of information technology that would be the base for planning and decision making. The study area is located in the western side of the Nile River in Beni Suef Governorate, which forms promising areas for agricultural horizontal expansion. The aim of this study is to setup a soil database as a local condition from the obtained data using imagery data and geographic information system GIS techniques. Based on the field survey, laboratory analysis and satellite image interpretation incorporation with GIS, the physiographic map was executed. The soil parameters (e.g. surface slope, $CaCO_3$ content, texture class, soil depth, salinity, alkalinity and drainage condition) were linked with the landform map units. The thematic layers of the selected soil properties were created in Arc-GIS platform through the spatial analyst function. These layers were matched to produce main soil capability levels. The soil properties and description of the geographic distribution of major landforms and dominant land cover were presented in detail. The results indicate that soils were categorized as high, marginal, low and very low capability. The dominant constrains in the study area are attribute to shallow soil depth, coarse texture, poor drainage and salt abundant. Optimum land use and appropriate rural management strategies are essential for sustaining the agricultural land use planning.

Key words: Thematic mapping, soil capability classification, landforms, GIS, spatial analyses, west of Nile Valley, Egypt.

Introduction

The area selected for this study is located to the west of the Nile Valley and extends from Biba to Bani Mazar districts. It considered as one of the most promising areas for sustainable agricultural development. In this area, the river Nile is the main source of irrigation for the alluvial plain soils, while Bahr Yousef canal irrigated the desert plain soils. This situation provides sustained irrigation water in the investigated area. The physiographic influence on soil properties is recognized as it leads to evolution of the soil-landform relationship. In this context the landform can easily be recognized, and it also formed by the same geomorphic processes that were responsible for providing the substrate material of the soils (Gessler *et al*., 1995; Florinsky *et al*., 2002; Park and Burt, 2002; Henderson *et al*., 2005; Mini *et al*. 2007). The main objective of this study is to produce the physiographic and soil maps in digital format and set the correlation between soils and physiography in the study area.

The selected study area is located to the west of the Nile Valley and extends from Biba to Bani Mazar districts at the south. It is bounded by longitudes 30° 32' 07" - 30° 57' 15" East; and latitudes 28° 24' 54" - 29° 05' 23" North. The Eastern border is limited by the river Nile, while the Western one extends about 10-15 km west of the Western desert road, where its main accessibility way. It covers an area of approximately (2704) km^2, where exhibit the old cultivation (1235) km^2 and arable land (1469) km^2 in the desert deposits (Fig. 1) The main geological deposits in the study area are Nile deposits, sand dunes, Aeolian deposits, gravels and basalt (CONOCO 1987).

According to Abu El-Izz (2000) the studied area is built of the sediments of recent alluvium, Pleistocene, and Pliocene periods. The area under investigation falls under the arid condition as the total rainfall is (4-7.8) mm/year.

Corresponding Author: M.A. Elsemary, Soils and Water Use Dept., National Research Centre (NRC) Egypt.
E-mail: semary304@yahoo.com

The dryness is prevailing most of the year and the wet periods are comparatively short. Based on the Egyptian Meteorological Authority (2000-2009) data and Soil Taxonomy System USDA, (2010), the soil temperature regime of the studied area is defined as Thermic, and the soil moisture regime as Torric.

River Nile is the main source of irrigation water in the study area, where dense network of irrigation canals were distributed to for the fertile soils in the flood plain. It also characterized by a good drainage network. For the recently cultivated areas west of the study area Bahr Yousef canal is the main source for irrigation with condensed surface drainage network (Fig.2).

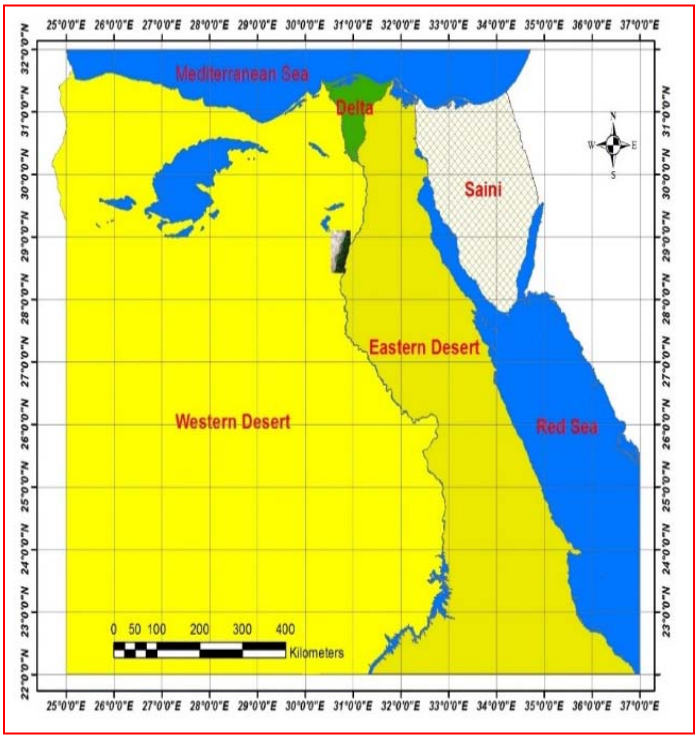


Fig. 1: Location of the studied area on Egypt.

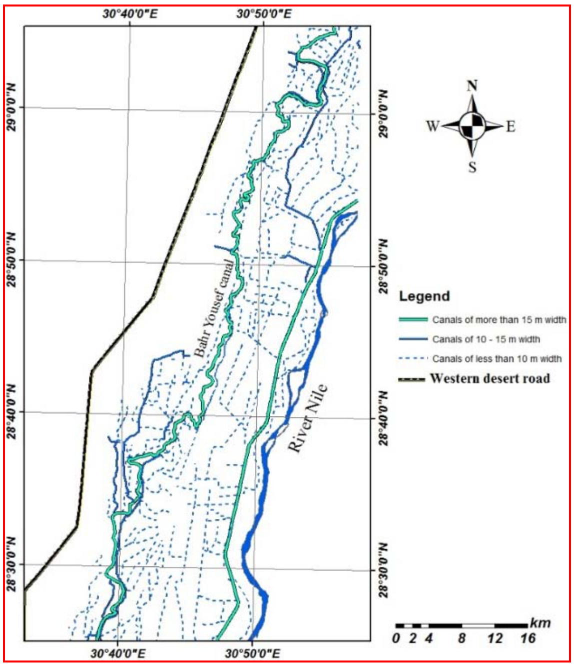


Fig.2: Irrigation network of the studied area.

Materials and Methods

- *Remote sensing:*

Landsat is one of the most important sources of satellite data. The Landsat 7 Scan Line Corrector (SLC) was failed in May 31, 2003 but the satellite still to gain data generating ETM+ images of about 22% missed data Storey *et al*., (2005). In order to recover the capability of the image of the study area, the SLC-off data is replaced with calculated values using ENVI 4.7 software. Several image processing techniques were applied to the satellite data of the study area following which visual interpretation and map construction were performed employing the resulting images. These processing techniques are as the following:

- *Geometric and atmospheric correction:*

Accurate per-pixel registration of multi-temporal remote sensing data is essential for change detection since registration errors could be interpreted as land-cover and land-use changes, leading to an overestimation of actual change Stow, (1999). Image processing is performed on a pixel-by-pixel basis; therefore any mis-registration greater than one pixel will provide an anomalous result of that pixel. To overcome this problem, geometric correction was carried out using ground control points from topographic maps to geocode the image. The atmospheric correction was done to reduce the noise effect using ENVI FLAASH module.

- *Image enhancement and visual interpretation:*

The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features. To improve the image contrast it was stretched, smoothly filtered, and their histograms were matched according to Lillesand and Kiefer (2007). The process of visually interpreting digitally enhanced imagery attempts to optimize the complementary abilities of the human mind and the computer. The mind is excellent at interpreting spatial attributes on an image and is capable of identifying obscure or subtle features Lillesand and Kiefer, (1994). Contrast stretching was applied on all images and the False Color Composites (FCC) has been produced. These FCC are visually interpreted using on screen digitizing in order to delineate land cover classes that could be easily interpreted such as urban and water.

- *Digital Elevation Model (DEM):*

Digital Elevation Model (DEM) is a 3D electronic model of the land's surface Brough, (1986). It provides better functionalities than the topographic maps. A DEM can be employed to offer varieties of data that can assist in mapping of landforms and soil types. Information derived from a DEM, i.e. surface elevation, slope % and slope direction, could be used with the satellite images to increase their capabilities for soil mapping Lee *et al*., (1988). The Shuttle Radar Topography Mission (SRTM) is one of the most significant space surveys of earth ever undertaken, using precisely positioned radar to map its surface at intervals of 1-arc seconds (~30 meters). The SRTM data can be used in conjunction with controlled imagery sources to provide better visualization of the terrain.

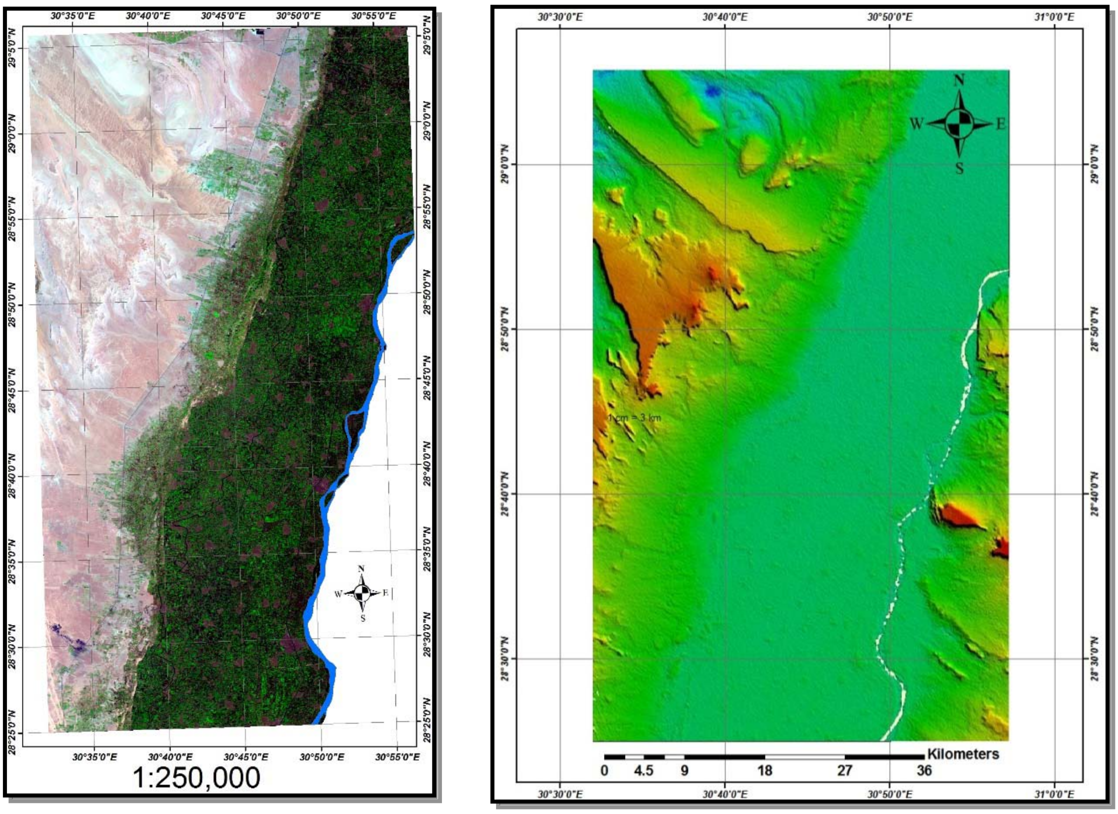
- *Physiography and soil mapping:*

The Landsat ETM+ image acquired in 2011 (path 176 /row 40) was used with the digital elevation model DEM in sort of SRTM data (Figure 3 A & b) to produce the physiography and soil map of the study area. The physiographic units have been extracted from the satellite image (i.e. landsat ETM+, and STRM) and land surveying data, Arc-GIS 9.2 and ENVI 4.7 software's were used Dobos *et al*. (2002). The physiographic units were classified according to their landscape, relief, lithology, landforms and soil (Zinck and Valenzuala, 1990). The produced map boundaries have been checked during the field work throughout 76 soil augers and observation points.

- *Land surveying and laboratory analyses:*

Satellite data analyses generate a preliminary physiographic map which needs to be checked and revised through field observation. A semi detailed survey was carried out throughout the investigated area in order to gain an appreciation on soil patterns, physiography and the landscape characteristics. A total of 14 soil profiles were collected to represent the revised mapping units. The morphological description of the profiles was carried out according to the guidelines outlined by FAO (2006). Laboratory analyses were carried out using the "soil survey laboratory methods manual" USDA (2004).

J. Appl. Sci. Res., 9(11): 5609-5618, 2013



(A) **(B)**

Fig. 3: Landsat ETM+ (A) and Digital Elevation Model of the study area (B).

On the other hand, ALESarid-GIS evaluation model was used in this research to assess land capability and come to a comparison conclusion. This system stands for Agriculture Land Evaluation System ALES for arid and semi-arid regions and been developed by Ismail *et al*. (2005). The main objective of land resources assessment for agriculture is to predict future conditions after development has taken place. It is necessary to forecast the benefits to farmers and the national economy and whether these will be sustained. The main data input used for this software includes the following parameters:

a. **Water characteristics**; Electrical Conductivity (dS/m), adj. SAR, pH, Na (meq/L), Cl (meq/L), Mg (meq/L), HCO (meq/L) and Boron (ppm).

b. **Soil properties**; Soil texture (Clay %), structure (Class), depth (cm), slope (%), $CaCO_3$ (%), ESP, EC (dS/m) and CEC (meq/100 g. soil).

c. **Fertility status**; Organic matter (%), Nitrogen (ppm), Phosphorus (ppm) and Potassium (ppm).

d. **Environmental setting**; Climate, geographical location, irrigation and drainage systems, dominant crops and communication status.

Results and Discussion

1. Study area's physiographic:

The dominant geomorphic features were delineated based on the Enhanced ETM+ satellite image, acquired DEM (Digital Elevation Model), ground truth data and geological formations covering the study area. Accordingly, satellite images interpretation indicated that the study area includes three main physiographic units, namely:

- Flood plain (F).
- Interference zone (I).
- Desert plain (D).

The produced map was imported into a Geo- database as a base map (Figure 4) and Table (1)

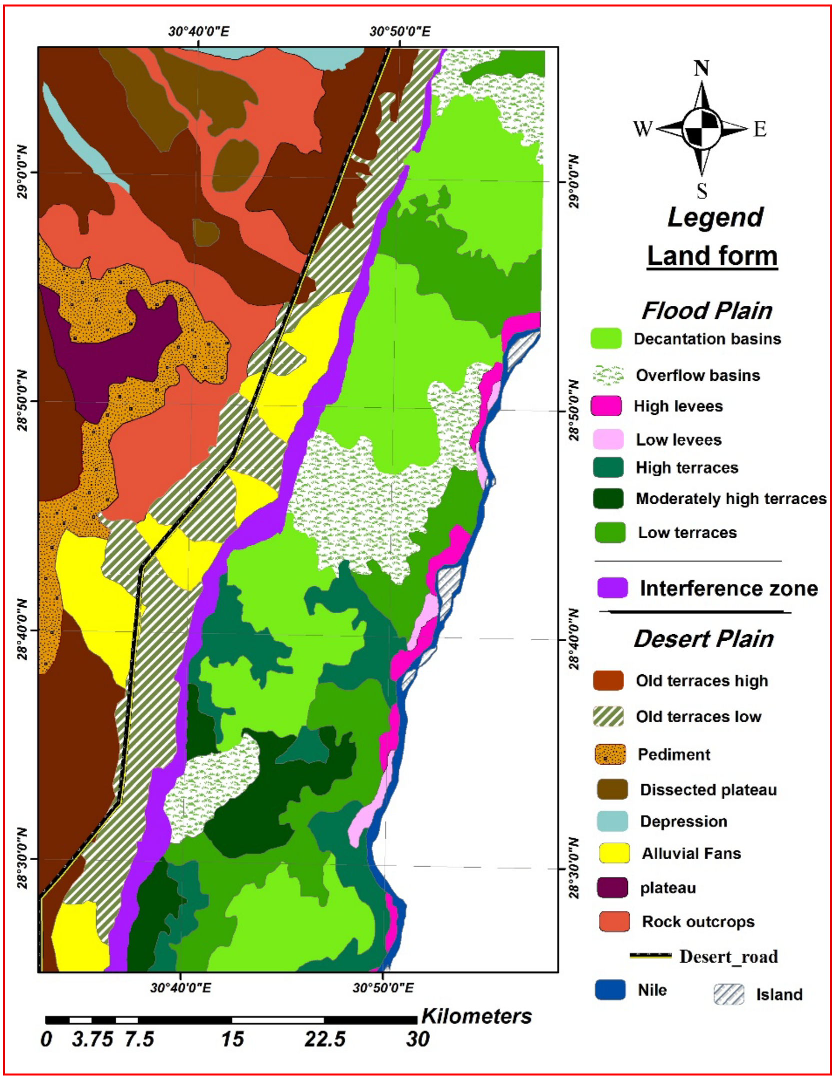


Fig. 4: Physiographic units of the area under investigation.

❖ *Soil of flood plain (F):*

Soils of flood plain landscape represents 43.62% of the study area with an area of about 1137.06 km2. It includes the river levee landforms close to the river Nile with an elevation 23m to 26 m (a.s.l.). It divides into high levee (32.38 km2) and low levee (14.23 km2). Besides, the river terraces of various elevations (30 – 35 m above sea level a.s.l.) occupy several locations of the flood plain. Topographically, the river terraces divided into; low, moderate and high terraces with areas of 229.34, 91.76 and 138.06 km2 respectively. Nevertheless, Basins are considered dominant landform in the flood plain and occupying an area of 631.19 km2 (i.e. 23.34 %). It includes overflow and decantation basins with areas of 193.91 and 437.21 km2 respectively.

❖ *Interference zone (I):*

This landscape occupies an area of 98.78 km2, which represents 3.65% of the study area. It exist between the desert and flood plain landforms. In the area under investigation, the interference zone's surface elevation changes from 40 to 45 m (a.s.l.).

❖ *Desert plain (D):*

The desert plain is distinguished into the following landforms sequence; alluvial fans (141.25 km2), depression (24.35 km2), dissected plateau (70.15 km2), high old terraces (465.63 km2), low old terraces (261.30 km2), pediment (153.08 km2), plateau (53.14 km2) and rock outcrops (257.34 km2). This desert plain landscape dominates an area of 1426.24 km2. The surface elevation of it is significantly increased from the east to west direction. Nevertheless, the elevation level differ from landform to another, where it closed to 50 m in alluvial fans, 52 m for the depression, 85 m for the dissected plateau, 70 m for the high old terraces, 55 m for the low old terraces. Concerning the pediment, rock outcrops and plateau the surface elevation reached 105, 135 and 239 m a.s.l. respectively.

Table 1: Legend of physiographic – Soil map of the studied area.

Area %	Area Km^2	Mapping unit	Land forms	Relief	Origin	landscape
5.11	138.06	Ft111	High terraces (1)	Gently undulating (1)	Alluvial deposits (1)	Flood plain (F)
3.39	91.76	Ft112	Moderately high terraces (2)			
8.48	229.34	Ft113	Low terraces (3)			
7.17	193.91	Fb121	Overflow basins (1)	Gently slope (2)		
16.17	437.28	Fb122	Decantation basins (2)			
1.20	32.38	Fl121	High levees (1)			
0.53	14.23	Fl122	Low levees (2)			
3.65	98.78	Ii211	Interference zone (1)	Gently undulating (1)	Aeolian/ alluvial deposits (2)	Interferences Zone (I)
17.22	465.63	Dt311	Old terraces high (1)	Gently undulating (1)	Aeolian/ deposits (3)	Desert plain (D)
9.66	261.30	Dt322	Old terraces low (2)			
5.66	153.08	Dp331	Pediment (1)	Undulating (3)		
2.59	70.15	Du241	Dissected plateau (1)	Hilly (4)	Aeolian/ alluvial deposits (2)	
0.90	24.35	Dd211	Depression (1)	Gently undulating (1)		
5.22	141.25	Df211	Alluvial fans (1)			
86.4	2351.49	Total				
1.97	53.14	Plateau				
9.52	257.34	Rock outcrops				
0.38	10.25	Island				
1.19	32.16	Nile				

2. *Soil classification:*

According to the field work, laboratory analyses, and Keys to Soil Taxonomy (USDA 2010), the soil of the identified mapping units could be classified. The soils were classified mainly as *Typic Torrifluvents, Vertic Torrifluvents, Typic Torriorthents, Typic Torripsamments* and *Typic Haplosalids.*

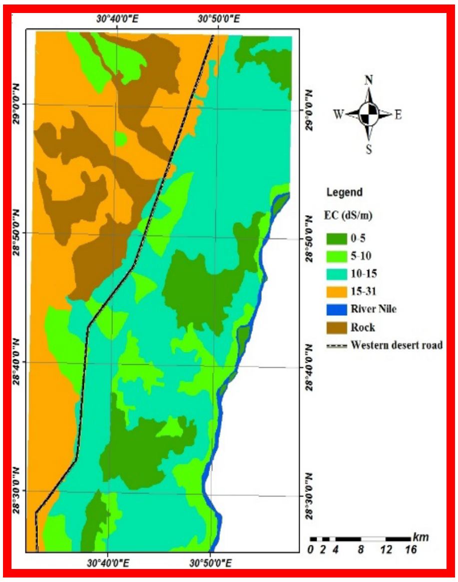
3. *Spatial analysis:*

The spatial analyst technique was used to map the soil characteristics using the field observation and laboratory analysis data. Figures (5 to 8) represent the produced thematic layers of soil characteristics i.e. EC, $CaCO_3$, CEC, and ESP.

4. *Land quality index:*

Based on the water, soil properties, fertility status and environmental characteristics of the investigated area the land quality index have been estimated using the Applied System for Land Evaluation (ASLE model). The obtained results are illustrated in Table (2). The environmental data used in this study include climatic data, geographic location, irrigation and drainage system, dominant crops and communication status. The soils and environmental quality index is differing widely over the study area. The indices of soil, water, fertility and water index is excellent (C1) in the different studied landforms. The obtained soil indices differ from good (C2) to non-agriculture (C6), the low indices characterize the desert plain landforms. Fertility index varies from C3 (Fair) to C6 (non-agriculture) the high values of fertility index characterize the flood plain. The overall quality index (land quality index) was extracted from the indices of soils, water, fertility and environment. The results indicate that the estimated quality index for land differs from C6 or non-agriculture (9.58) to C2 or good (65.46). The modeled quality indexes for each parameter (soil, water, fertility and environment).

J. Appl. Sci. Res., 9(11): 5609-5618, 2013



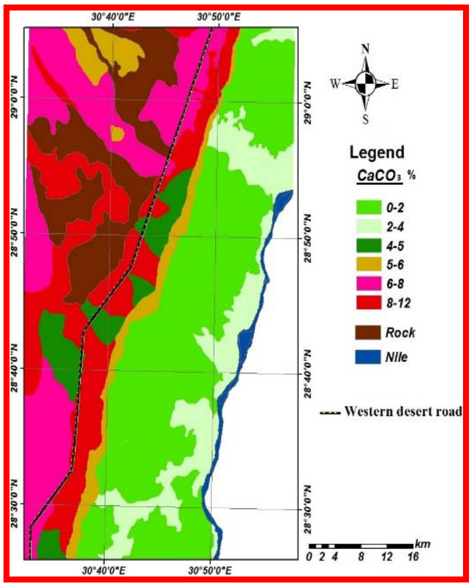
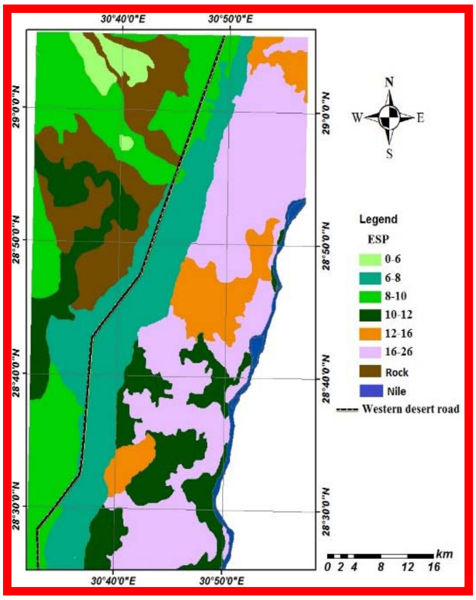


Fig. 5: Spatial distribution of soil salinity in the studied area.

Fig. 6: Spatial distribution of $CaCO_3$ content in the studied area.



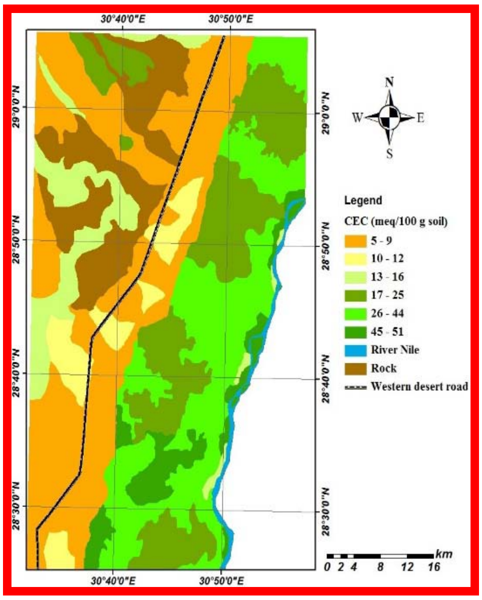


Fig. 7: Spatial distribution of CEC in the studied area.

Fig. 8: Spatial distribution of soil alkalinity in the studied area

The soil capability map of the study area was produced (Figure 9) by using the Geographic Information System (GIS) considering the physiographic map as the base layer. Description and areas of the different land quality classes are illustrated in table (3). The results indicate that the soils of high and moderately high terraces in the flood plain have a C2 (good) quality index representing 8.50 % of the total area. Soils of the low terraces, decantation and overflow basins have a C3 (Fair) quality index representing 33.92% of the total area. The soils of river levee in the investigated area have a C3 (high levee) and C4 (low levee) representing 0.53 % of the total area.

The land quality index of the desert plain soils differs from C3 (Fair) to C6 (non-agriculture). The soils of the depressions are characterized by a fair quality index (C3) representing 0.9 % of the total area. The soils of dissected plateau and alluvial fan are characterized by a quality index of C4 (Poor) representing 7.81 % (where about 0.53% are C4 characterized the river levee). The soils of low old terraces, pediment and interference zone have a C5 quality class (Very poor) dominating about 18.98 % of the total area. The non-agriculture (C6) areas are found in the high old terraces representing 17.22 % of the total area.

It is found that the main limiting factors are soil depth, phosphorous content and salinity in the flood plain soils. On the other and the soils texture, fertility status and salinity are the main limiting factors in the desert plain.

Table 2: The quality index of soil, water, fertility and environment and the final land quality index of the studied landforms.

Mapping unit	Profile No.	Quality Index				Land quality Index
		Soil	Water	Fertility	Environmental	
Ft112	1	C2 62.73	C1 95.00	C3 50.95	C2 64.86	C2 65.03
Ft111	2	C2 64.01	C1 95.78	C3 50.95	C2 64.86	C2 65.46
Ft113	3	C3 42.29	C1 97.87	C4 32.81	C2 64.86	C3 50.15
Fb121	4	C3 56.59	C1 98.95	C4 21.16	C2 64.86	C3 44.2
Fb122	5	C3 49.14	C1 96.13	C5 19.71	C2 64.86	C3 41.28
Fl121	6	C3 57.83	C1 95.09	C4 25.02	C2 64.86	C3 48.08
Fl122	7	C3 47.48	C1 98.29	C5 16.25	C2 64.86	C4 36.98
Ii211	8	C3 58.89	C1 98.67	C6 16.22	C2 64.86	C5 18.16
Du341	9	C4 20.41	C1 98.31	C6 32.66	C2 64.86	C4 20.4
Dp331	10	C4 20.41	C1 98.31	C6 7.36	C2 64.86	C5 19.01
Dt311	11	C6 3.70	C1 98.67	C6 32.66	C2 64.86	C6 9.59
Dt322	12	C3 44.88	C1 98.67	C6 19.47	C2 64.86	C5 19.75
Dd311	13	C3 40.92	C1 98.67	C4 22.33	C2 64.86	C3 42.21
Df311	14	C2 66.65	C1 98.67	C6 9.37	C2 64.86	C4 27.16

C1=Excellent (80-100) C2=Good (60-80)
C3=Fair (40-60) C4=Poor (20-40)
C5= Very poor (10-20) C6=Non-agriculture (0-10)

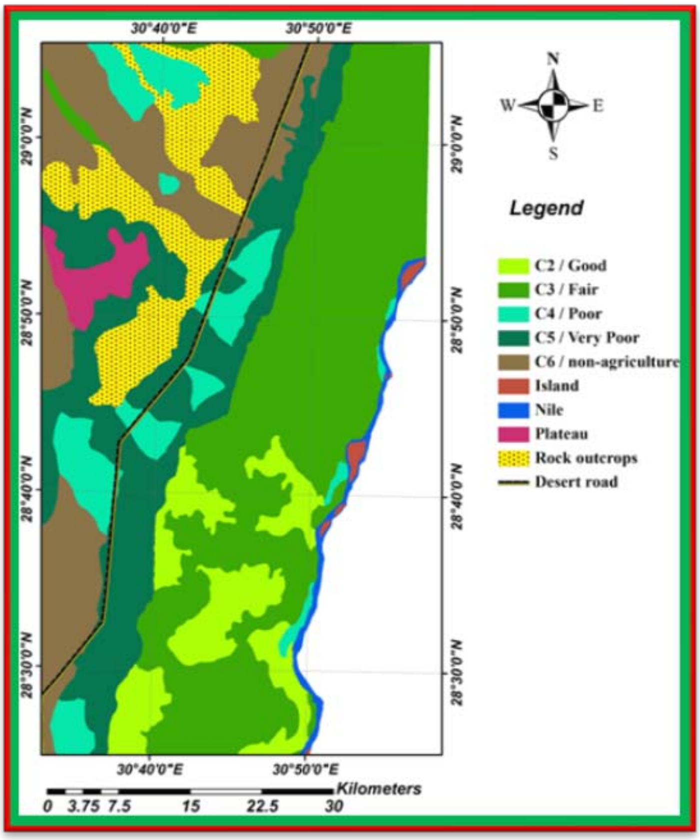


Fig. 9: Land capability map for the study area.

Table 3: Description and area coverage of the capability classes in the study area.

Capability class	Description	Area Km^2	Area %
C2 Good	Soils are suited for cultivation over a long period of time and have few limitations that restrict their use. They are deep, nearly level, well to moderately-well drained.	229.82	8.50
C3 Fair	Soils are suited for cultivation over a long period of time, but they have some hazards and limitations that reduce the choice of plants or require moderate conservation practices that are easy to apply.	917.26	33.92
C4 Poor	Soils are good for cultivated crops, but have severe limitation that reduce the choice of plants and/or require special conservation practices that are more difficult to apply. Terracing and other water control measures will be needed.	225.63	8.34
C5 Very Poor	Soils can be cultivated crops, but have severe limitations that restrict the choice of plants, require very careful management, special conservation or both.	513.16	18.98
C6 non-agriculture	The soils cannot be cultivated at the current condition	465.63	17.22
Others	Water bodies, rock land, Island and plateau	352.89	13.06

Conclusion:

The conclusions drawn from this study indicate that, geospatial analysis offers the potential to automate and simplify the collection and analysis of information. It allows management decisions to be made and quickly implemented on management zones within the fields. This research reaffirms the importance of imagery and spatial data analysis in defining the main landforms and soil phases of the area at a regional scale. In regard to the obtained capability classification, it is found that soils with much variability seemed to be more responsive to management practices, i.e. vertical drainage management and optimum fertilizers input in the desert plain soils. On the other hand, water consumption, leashing requirements balanced with irrigation network and land use planning should be followed in the flood plain soils. The generated multi-thematic layers of land characteristics, highlight the relationship between landforms and soil qualities, which can be used in extrapolation of soil characteristics in the different landforms, accordingly suitable suggestions could be attained to understanding how to deal with these soils for sustainable agricultural use.

Finally, achieving such detailed geo-database is rather important in documenting the environmental themes. The obtained thematic layers in the database and such information would be the base for planning, decision making and research needs.

References

Abu El-Izz, M.S., 2000. Land forms of Egypt. The Amer. Univ. in Cairo Press. Dar Al Maaref, Cairo Egypt.

Brough, P.A., 1986. Principle of Geographical Information Systems for Land Resources Assessment. Oxford University Press, 194.

Conoco Coral, 1987 Geological map of Egypt 1:500 000, NH 36 Sw Beni Suef. Egyptian General Petroleum Corporation.

Dobos, E., B. Norman, W. Bruee, M. Luca, J. Chris and M. Erika, 2002. The use of DEM and satellite images for regional scale soil database. Proceedings of the 17th World Congress of Soil Science, August 14-21, 2002, Bangkok, Thailand.

FAO, 2006. Guidelines for soil description. 4th edition. FAO, Rome, Italy.

Florinsky, I.V., R.G. Eilers, G.R. Manning, L.G. Fuller, 2002. Prediction of soil properties by digital terrain modelling. Environ. Model. Software, 17: 295-311.

Gessler, P.E., I.D. Moore, N.J. McKenzie, P.J. Ryan, 1995. Soil-landscape modelling and the spatial prediction of soil attributes. Int. J. Geogr. Inf. Syst., 95: 421-432.

Henderson, B.L., E.N. Bui, C.J. Moran, D.A.P. Simon, 2005. Australia-wide predictions of soil properties using decision trees. Geoderma, 124: 383-398.

Ismail, H.A., M.H. Bahnass, O.R. Abd El-Kawy, 2005. Integrating GIS and modelling for agricultural land suitability evaluation at East Wadi El-Natrun, Egypt. Egyptian J Soil Sci., 45: 297-322.

Lee, K.S., G.B. Lee and J. Tyler, 1988. Determination of soil characteristics from thematic mapper data of a cropped organic- inorganic soil landscape. Soil Science Society of America, 52: 1100-1104.

Lillesand, T.M., R.W. Kiefer, 1994. Remote Sensing and Image Interpretation. 4th edition, New York, John Wiley and Sons.

Lillesand, TM., R.W. Kiefer, 2007. Remote sensing and image interpretation, 5th ed. Paper back September 2007, John Wiley, New York, pp: 820.

Mini, V., P.L. Patil and G.S. Dasog, 2007. A Remote Sensing Approach for Establishing the Soil Physiographic Relationship in the Coastal Agro Eco system of North Karnataka. Karnataka J. Agric. Sci., 20(3): 524-530. November 2004.

Park, S.J., T.P. Burt, 2002. Idenfication and characterization of pedo -geomorphological processes on a hill slope. Soil Sci. Soc. Am. J., 66: 1897-1910.
Storey, J.C., P. Scaramuzza and G. Schmidt, 2005. Landsat 7 scan line corrector-off gap filled product development. PECORA 16 Conference Proceedings, Sioux Falls, South Dakota, pp: 23-27.
Stow, D.A., 1999. Reducing mis-registration effects for pixel-level analysis of land-cover change. International Journal of Remote Sensing, 20: 2477-2483.
USDA, 2004. Soil Survey Laboratory Methods Manual. Soil Survey Investigation Report No. 42 Version 4.0.
USDA, 2010. Keys to Soil Taxonomy, United State Department of Agriculture, Natural Resources Conservation Service (NRCS) eleventh edition.
Zinck, J.A. and C.R. Valenzuela, 1990. Soil geographic database: Structure and application examples. ITC J., 3: 270-272.