Terrain Analysis as a Criterion for Soil Attributes at Wadi Al-Shobeity, Northwestern Coast, Egypt

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ABSTRACT

Pedology has developed recently to include quite precise quantified methodologies for soil spatial distribution. These are generally based on the hypothesis that soil properties have distributed spatially over landscape through repeated patterns according to soil forming factors and processes. This study is based on the concept that catenary soil evolution is characterizing watershed basins in response to terrain features which guide drained water movement through or over land surface and consequently affect sediments and solutes transport and redistribution. Studied location occupies 1920 feddans representing the catchment basin of Al-Shobeity watershed which locate 68 km west of Mersa Matroh. As a toposequence, soils have been surveyed through the observation of thirty soil profiles, along a couple of parallel transects crossing the existing geomorphological units starting from southern plateau towards northern coastal plain. According to field survey and laboratory analysis eight soil mapping units have been differentiated with respect to profile depth, texture, and salinity. Accordingly, about 59.77% of the area is dominated by moderately deep soils, whereas deep and very deep ones covering only 21.6 % of the whole area. Most soils (88.4%) are sandy loam to sandy clay loam in texture. The area is dominated by slightly - to moderately saline soils, only 26.7% of the entire area is considered saline. DEM was generated over grid resolution 100 m, and then used to calculate primary topographic attributes which include slope, aspect, specific catchment area, maximum flow path, and profile curvature. Secondary terrain indices including wetness, stream power, and sediment transport indices were calculated and mapped. Results revealed that elevations of Al-Shobeity watershed decrease downward from 80 to 5 m ASL, in which surface slopes range between 0.3 and 8.4 %. Gentle slopes (1-2%) cover 52.8 % of the ground surface while slopped sites (5-10%) were found covering only 8.4 % of the entire area. The basin is classified into three classes according to wetness index where 25.8 % of the area is considered "saturation zone". Generally, sediment transport and stream power indices have non significant values except for some scattered zones over 17.5% and 21.6%, respectively, of the total area. Correlation matrix showed that slope is the highest correlated primary terrains attribute orderly with profile depth, salinity, sand, silt, clay, pH, and lime, where correlation coefficient ranged between 0.58 and 0.81. While wetness index was the most correlated secondary terrain quality orderly with sand, profile depth, clay, silt, and salinity, where correlation coefficient ranged from 0.51 – 0.77. Deep and very deep soils don't exist unless slopes and wetness index were less than 1% and more than 5, respectively. Moreover, saline soils don't occur at slopes and wetness index more than 2% and less than 5, respectively. Stepwise linear regression analysis was used to relate numerically topographic attributes with soil properties. Significant regression coefficients were achieved at 0.01 significance level for soil depth, salinity, sand, and clay, respectively, as 0.68, 0.48, 0.55, and 0.40. Spatial distribution of estimated soil depth, texture, and salinity were mapped based on topographic attributes, and then compared with actual soil properties. Reasonable similarity degree was achieved between measured and estimated soil spatial distribution based on low standard error of prediction, in addition to finding out details and variations inside each soil mapping unit. This study indicate that the terrain-based technique carried out in Al-Shobeity watershed basin has shown a rather successful results concerning the estimation of soil attributes for more than 75 % of the total tested sits. Extrapolation trials may be done to enhance detection of soil variation at traditional maps which permit minimization of costs, efforts, and time.

Keywords: Terrain analysis- Soil properties– Soil survey – Soil mapping – Correlation analysis– Regression analysis- Rainfed - Wadi Al-Shobeity – Northwestern coast of Egypt.

INTRODUCTION

Soil survey has played a key role in the development of pedology, and soil maps have become valuable tools for natural resources managements (Simonson, 1991). But, standard soil surveys were not designed to provide the high-resolution (about 1:5000) models and maps of the soils continuum required in detailed environmental modeling applications and site specific crop managements (Peterson, 1991). Traditional soil survey is associated with existing of some problems including: (1) Traditional soil map neither delineate all of the general field's variability nor represent specific soil attribute variation, (2) Ranges of some soils attributes (e.g. hydraulic properties) often vary by an order of magnitude, (3) The nearest sampled pedon used to derive a mapping unit (for specific soil attribute) could be kilometers from the point of interest, (4) Creating detailed soil maps (1:5000) is expensive by traditional methods. Thus, accurate and inexpensive quantitative

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alternatives are needed (Burrough, 1986; Gessler, 1990).

There have been many attempts to characterize the spatial variability of measured soil attributes (Webster, 1985; Yates and Warrick, 1987; Loague and Gander, 1990; Gopu *et. al.*, 2011; Tomer et. al., 2003). These attempts have concentrated on the characterization of patterns, rather than on the linkage of pattern to process. Quantitative interpolation techniques (e.g., kriging) often ignore pedo-genesis, while methods based on landscape position have lacked a consistent quantitative framework (McBratney *et al*., 1991). Methods that organize the land surface according to land form modeling show potential for improving soil attribute prediction, that is because geomorphological position influences horizonation and soil attributes (Moore et al., 1993). The relationships between topographic attributes and erosinal processes occurring in landscapes have been outlined by Speight (1974), Moore et al., (1991), Wilson and Gallant, (2000), and Florinsky, (2012). Martz and De jong (1991) stated that, "The general pattern of association between soil loss and land form class supports the earlier suggestion that water is the dominant erosional agent in the basin. Low soil loss is associated with sites of low catchment area".

The North West Coastal zone of Egypt extends over 350 km from west of Alexandria to the Libyan border. There are 218 drainage lines cutting the area with their watersheds and sub-watersheds (FAO, 1970)**.** Land use is entirely dependent on rainfall and on various forms of water harvesting (Moustafa, 1994). Annual rainfall is restricted to the winter months and to a narrow 20 km strip along the coast, where the 60 years average at Mersa Matrouh is 144 mm (Abdel-Kader and Fitz Simon, 2002). Potentially productive areas in terms of runoff accumulation and soils are concentrated within a small number of wadis and depressions (Abdel-Kader, *et al*. 2004).

This study represents an incorporation of based information process in relation to soil formation patterns in the landscape, based on the hypothesis that catenary soil development occurs in many landscapes in response to the way water moves through and over the landscape (Buol *et al*., 1989). Furthermore, terrain attributes can characterize these flow paths and therefore, soil attributes. For this study, the chosen site at Al-Shobeity valley catchment area, west Matrouh has relatively uniform parent material, so that a large proportion of the local soil variation can be attributed to changes in landforms. The overall objective of this study is to estimate some soil properties according to their confirmed relations with topographic attributes. Coupling between Geographic Information System (GIS) and landscape modeling is essential for Digital Elevation Model (DEM) creation and soil attributes prediction through statistical framework (Burrough and McDonnell, 1998).

STUDY AREA

1- Site:

Studied location occupies an area of about 1920 feddans representing the catchment basin of Wadi Al-Shobeity which lies 68 km west of Mersa Matroh in the Northwestern coastal region of Egypt. The area is bounded by latitudes 31° 26' 30" and 31° 29' 30 N and longitudes 26° 38' 00" and 26° 38' 40" E. as shown in map (1).

2- Geology:

The area under investigation is dominated by a sedimentary succession ranging from Middle Miocene to Quaternary. The Middle Miocene sediments are widely spread in the table land. Quaternary deposits are differentiated into Pleistocene formation and Holocene geologic and environmental units which have wide distribution and constitute the bulk of the coastal plain (El-Shazely *et. al*., 1975)

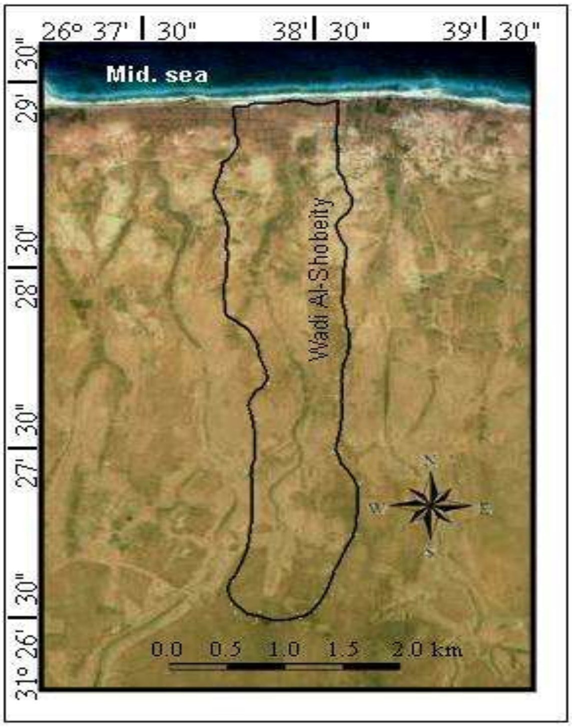
3- Hydrology

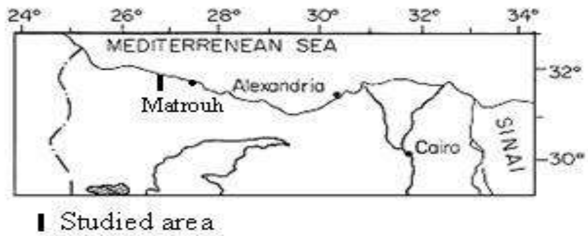
The studied area is characterized by an unstable rainy winter and a stable warm and dry summer. The distribution of the rainfall along the coastal zone is not even, its average amount ranges between 102 mm at Sallum and 180 mm at Alexandria. The amount of rainfall shows steady decrease in the inland direction where it reaches about 50 mm within the southern limit of the defined catchment area of the coastal zone (FAO, 1970). Consequent deep wadis found in the area cutting the table land drain its water towards the Northern semi-closed depressions in the coastal plain.

Temporary surface run off occurs immediately after rainy periods and represents a definite percentage of the rainfall. Water run off differs from one locality to another depending on some factors such as slope, ground topography, nature of cap rock, field water capacity and the catchment area.

4- Geomorphology

The study area could be characterized geomorphologically as a coastal plain bounded inland by first escarpment of the northern elevated plateau as a part of Marmarica formation belonging to Lybian Plateau. That plateau could be subdivided, with regard to the nature of drainage systems into eastern, central and western sectors. The western sector extends between Ras Om El-Rakham and El-Sallum along 110 km where the plateau lies very close to the sea.





Map1. Location of Wadi Al- Shobeity, West of Matrouh.

The elevated plateau or table land is dissected at the eastern portion by numerous deep and long high density drainage lines or wadis. Most of these wadis end in the piedmont plain or the coastal plain which are formed mainly of Marine deposits and contain some longitudinal sand dunes formed by eolian deposition. The depth of these wadis ranges between 20 and 50 m. The majority of them have certain morphologic features allowing the construction of dykes for soil and water conservation. At the foot slopes of the plateau, an aggradational piedmont resulted from the coalescence of the fans of the dissecting wadis is well developed (Abu El-Izz, 1971). Wadi Al-Shobeity extends from South to North along 4.2 km cutting the lime plateau at 80 m A.S.L. and forming a very narrow and shallow stream. The stream becomes wider as attached to the terminal fan in the coastal plain at 10 m A.S.L. The lower catchment area is nearly level with very few surface gravels and varisized highly weathered limestone grits. While the upper catchment is obviously undulating with abundant rock fragments.

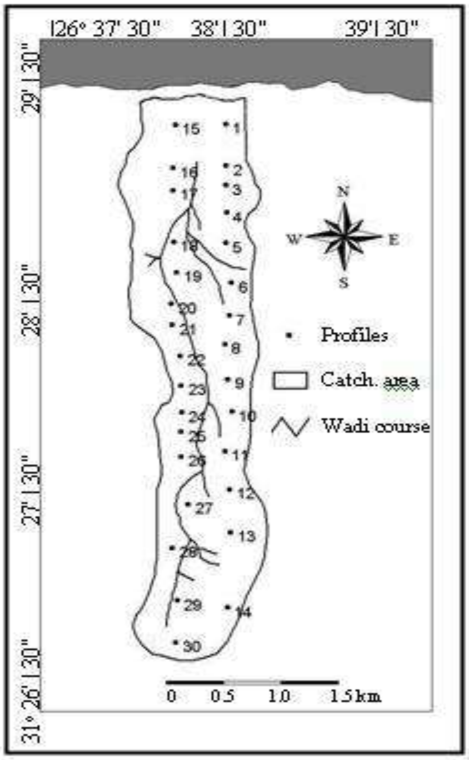
5- Land use:

The whole catchment area of Wadi Al-Shobeity is plowed for rain fed Barely and Wheat. Some scattered areas located in the down streams irrigated supplementary by ground water and cultivated with vegetables like Tomato, Piper and Cantaloupe, while the wadi course is fully occupied by Fig and Olive trees. Lots of cemented stony dykes are established between different levels along the stream (DRC, 2010).

MATERIALIS AND METHODS

1- Field work:

Area under investigation extending over 1920 feddans was surveyed using thirty soil profiles chosen along double transects delineated through the wadi catchment area. Location of soil profiles were chosen to represent topographic variation associated with different slope degrees along the descending ground heights over sea level from southern table land towards Northern costal plain (Map 2). Selected soil profiles were morphologically described according to FAO (2006). Seventy six soil samples were collected according to profile stratification for further laboratory analyses. Soil profile depth and A-horizon thickness were recorded.



Map 2. Soil Profile Loication at Wadi Al- Shobeity.

2- Soil analysis:

Collected soil samples were analyzed to determine (a) physical properties such as saturation percentage, gravels percentage, soil texture class based on sand, silt, and clay contents (Page *et al*., 1982); (b) chemical properties such as electrical conductivity (EC), soil reaction (pH) (Page *et al*., 1982) and total calcium carbonate (Jackson, 1973)

3- Modeling of Hydro-Terrain attributes using GIS:

A grid-based DEM was designed using ARC-GIS, 9.0 (ESRI, 2006) to cover 1920 feddans toposequence consisting of a single plot and encompasses a single catchment area of Wadi Al-Shobeity. The DEM was created at 100 m grid resolution in which coordinates of crossing nodes were identified over the studied area. Locations of studied soil profiles were chosen over 30 sites of the regular grid system. Some primary and secondary topographic attributes were calculated from the DEM grid based-system.

Primary topographic attributes were calculated directly from DEM, which include elevation (m A.S.L.), slope %, aspect (clockwise from N), specific catchment area (m^2m^{-1}), maximum flow path length (m), and profile curvature (m^{-1}). Profile curvature is a measure of the change rate of the potential gradient; therefore, it is very important for water flow and sediment transport process. A computationally efficient method of estimating primary terrain attributes from a grid–based DEM applies a second–order central finite difference scheme centered on the interior node of a moving three by three square grid network.

The secondary topographic attributes are parameters related to surface and sub surface water and sediment transport processes. They were included in an attempt to relate the pattern to process. The secondary indices involve combinations of the primary attributes and may be derived empirically or by simplifying equation related to the topographic aspects. Secondary attributes includes: (1) Wetness index (wi) which characterize the surface saturation and soil water in landscape, (2) Stream power index (spi) which is a measure of erosive power of over land flow, and (3) Sediment transport index (sti) which characterize the effect of topography on soil loss (Moore *et al*., 1991).

The wetness, stream power, and sediment transport indices, in their simplest form, can be expressed as mentioned by Moore and Wilson (1992), respectively, as:

$$\omega = In\left(\frac{As}{\tan\beta}\right),\ \Omega = As\tan\beta\ ,$$

$$\tau = \left(\frac{As}{22.13}\right)^{m}\left(\frac{\sin\beta}{0.0896}\right)^{n}$$

Where A*s* is the specific catchment area (m^2m^{-1}), β is the slope angle (degree), and m = 0.6, and n = 1.3.

The contour lines and ground control points of the topographic maps of the study area were used to create Digital Elevation Model "DEM" using ARC-GIS, 9.0 (ESRI, 2006). The DEM was prepared using the Geostatistical analyses through the best fit of an experimental semi-variogram model then elevations were interpolated using Ordinary Kriging (Stein, 1998). Based on created DEM, Al-Shobeity watershed was generated through DEM-Hydro Processing through 7 steps, starting with fill sinks, stream pattern, DEM optimization, flow direction, flow accumulation, drainage network ordering, and catchments extraction. Watershed areas are normally defined as the total area flowing to a given outlet. DEM also was used to calculate the slope (in degrees) and aspect (measured in degrees clockwise from north) maps of the catchment.

Drainage Network and sub-watersheds were identified to estimate the runoff volume in the drainage sub-basins using a rational formula (Abdel-Kader and Fitz Simon 2002). This formula uses three parameters: rainfall, drainage area and runoff coefficient based on the topography, land uses and soils characteristics of the drainage area. The runoff volume for each sub-basin in the watershed area is estimated at average annual rainfall equal to 150 mm.

Soil profile locations and associated spatial and attributed data were georeferenced using UTM coordinate system and exported to ARC-GIS, 9.0 (ESRI, 2006). Soil properties in different layers were overlapped to generate the soil map of the studied area.

4- Statistical analysis:

Multiple linear regression analysis was performed using SPSS software (SPSS, 2009) to relate soil attributes to topographic features. Stepwise regression was performed and only terrain attributes that significantly improved the regression were brought into regression at each step.

RESULTS AND DISCUSSION

1- General description of the studied area:

Area under investigation represents the catchment basin of Al-Shobeity valley which has considerable variation in elevations that obviously decreasing towards North. Ground surface is gently undulated in general and tend to be almost flat in the down stream. Weathered limestone grits covering most of the area and sometimes mixed with varisized gravels. Middle stream area is characterized by existing non weathered rocky layers which become very close to the surface and sometimes exposed particularly over the southern portion. The considered area was partially plowed for rainfed wheat and barely, while valley course is cultivated basically with figs and olives in addition to some vegetables. Valley down stream receptor area is forming a fan which is fully occupied by several fruit trees and vegetables.

2- Soil Mapping:

Based on the variations in soil depth, texture class and soil salinity shown in table (1) which summarizes soil properties, studied area were classified into eight soil mapping units as showed in map (3). Table (2) listed the definition of the grouped soil mapping units and their corresponding areas over the catchment basin of Al-Shobeity valley.

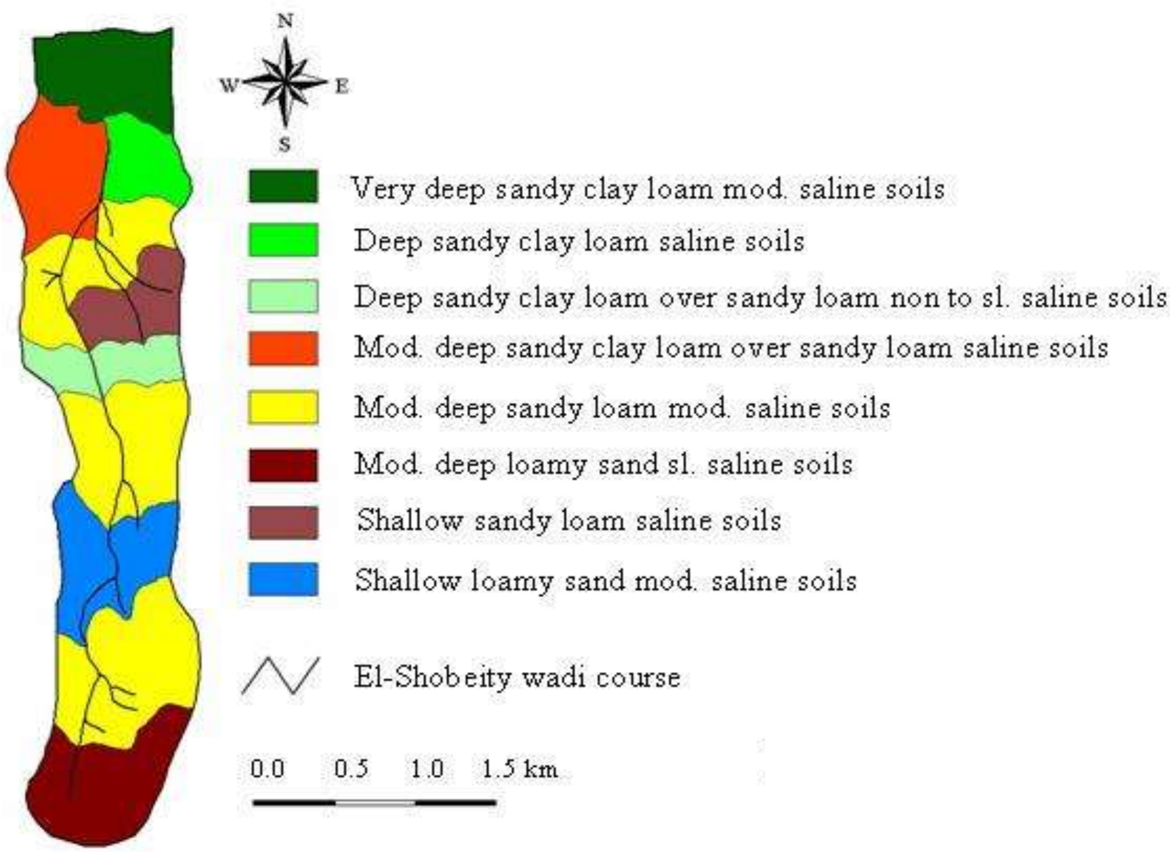
The analytical data of soils as seen in table (1) emphasizes that variation among the selected sites along the wadi are due to the differences in topography. Soil profile depth varied within four classes from 30 cm as shallow soil depth to 160 cm as very deep soil depth. Very deep soils occupy 9.2 % of the studied area while deep soils cover 12.4 % of the area. Most of the studied areas are considered moderately deep which represent 59.7%, while shallow soils cover areas of 18.7 %, (table 2 and map 3). Based on table (1) soils having medium to light soil texture classes ranged from sandy clay loam to loamy sand. Sandy clay loam soils locating close to coast over 21.6 % of the area, while coarser textures dominated the upper stream as seen in table 2 and map 3. Commonly, coarser soil texture approaching the bottom of studied profiles. Most of the studied soils were non to slightly gravelly where gravels ranged between 1.7 – 7.5 %.

Wide range of soil salinity was found, as measured electric conductivity varied from 1.5 dS/m (slightly saline) to 12.4 dS/m (highly saline)with moderate common tendency of salt decreasing with depth (table 1). Most of the investigated soils are considered to be moderately saline over 45.5% of the total area as indicated from table (2) followed by salt affected soils or saline soils over 41.2 %. On the other hand, soil reaction values were neutral to moderate alkaline tendency as pH ranged from 8.0 to 8.5 for the whole area. As usual at coastal sites, lime content is high with increasing tendency with depth. Soil calcium carbonate varied widely from 28.2 % to 42.5 %.

Table 1. Summarized data of selected soil mapping units at Wadi Al-Shobeity

Mapping Unit		**A**				**C**			**D**		**G**
Rep. Profile		**1**				**7**			**16**		**6**
Depth to – cm	25	85	120	160	50	100	140	15	60	80	30
Physical properties											
Profile depth		**Very Deep**				**Deep**			**Moderately Deep**		**Shallow**
SP %	18.4	20.5	21.2	16.6	22.2	18.0	15.4	18.8	14.4	15.5	14.2
Gravel %	4.2	1.7	2.5	3.4	5.2	6.4	3.8	3.5	4.2	5.8	7.5
Sand %	62.5	59.8	58.7	64.2	62.8	68.0	77.4	61.6	72.2	62.1	70.5
Silt %	15.1	14.8	17.3	17.3	15.8	13.8	7.3	16.0	17.3	24.5	18.0
Clay %	22.4	25.4	24.0	18.5	21.4	18.2	15.3	22.4	10.5	13.4	11.5
Texture class *	SCL	SCL	SCL	SL	SCL	SL	SL	SCL	SL	SL	SL
Chemical properties											
pH	8.1	8.1	8.2	8.3	8.0	8.2	8.3	8.2	8.3	8.5	8.4
EC dS/m	6.5	7.9	5.0	5.4	1.5	4.0	3.4	10.8	8.8	4.2	12.4
$CaCO_3$ %	34.5	32.4	38.7	40.2	28.2	30.4	33.6	35.1	41.6	42.5	32.8

* SL = Sandy Loam SCL = Sandy clay loam



Map 3. Soil Mapping Units of Wadi Al-Shobeity.

Table 2. Soil mapping units and corresponding areas at Al-Shobeity watershed.

Mapping Unit	R.S.P [1]	Description	Area (%)
A	1	Very deep sandy clay loam mod. saline soils	9.2
B	2	Deep sandy clay loam saline soils	5.3
C	7	Deep sandy clay loam over sandy loam sl. saline soils	7.1
D	16	Mod. deep sandy clay loam over sandy loam saline soils	12.8
E	18	Mod. deep sandy loam mod. saline soils	35.4
F	30	Mod. deep loamy sand sl. saline soils	11.5
G	6	Shallow sandy loam saline soils	8.6
H	25	Shallow loamy sand mod. saline soils	10.1

(1) R.S.P = Represented Soil Profile

3- Topographic attributes and indices:

DEM Map was created after glue the 16 contour value maps with 5 meter height interval. Fill sink and DEM optimization were used to improve the final DEM values map (Map 4 - a & b) which is used to create the catchments area. The analysis of digital elevation model (DEM) revealed that elevations of the studied area decrease gradually from 80 m A.S.L. at table land upper stream to 5 m A.S.L. towards the North adjacent to shore line, as shown in map (4 - a & b). Overall slope degrees were derived from DEM and ranged between 0.3 % and 6.2 % as seen in table (3). Slopes could be divided into five classes (FAO, 2006) indicating significant slope which cover a wide range from flat to sloppy surface. Table (4) and map (4 - c) illustrate the classes, areas and percentage of detected slope in the studied area where gently surface slope constitute about 52.8 % of the total acreage. The slope aspect of the area is derived from DEM and characterized by an obvious slope dominantly towards the North and Northwest directions (Table 3). Micro-relief varied between leveled and strong micro-relief corresponding to erosion effect (Table 3).

The wetness index (Wetind) identifies catchment areas in relation to the slope gradient to draw an idea of the spatial distribution for saturation zones or variable sources for runoff generation. Wetind is helpful for crops and range land improvement as well as identification of potential sites for water and soil conservation (Map 4 – D). Table (5) indicates that 25.8 % of Al-Shobeity watershed area has a significant wetness index indicating zones of saturation that could be considered in planning for crops and rangeland improvement. The sediment transport index (Sedtind) formulates the effect of topography on water erosion, consequently, on sediment migration downstream which affect mainly profile depth and soil texture. Sedtind was calculated over DEM network nodes and found with high values, associated with hazardous effect of erosion, comprising 17.5 % of the watershed area (Table 5). The stream power index (Strpind) is the product of catchments area and slope to indicate surface runoff. Strpind is used to identify suitable locations for soil conservation measures to reduce the effect of concentrated surface runoff. Strpind was calculated over generated DEM and found high serving 21.6 % of El-Shobeity watershed as seen in table (5).

4- Correlation between soil and terrain attributes:

Table (6) presents a matrix showing the correlation coefficients between pairs of variables belong to soil and terrain attributes. From this matrix it can be seen that slope as a primary terrain property is the most highly, positively or negatively, correlated with soil properties where (ǀ R ǀ = 0.58 – 0.81). Significant correlations with slope were found orderly with profile depth, salinity, sand and silt. Wetness index is the most highly correlated secondary terrain measure with soil properties where (ǀ R ǀ = 0.52 – 0.77). Sand and profile depth are orderly most correlated with wetness index. In addition, sediment transport index is moderately correlated only with some soil properties (ǀ R ǀ = 0.18 – 0.44). Except for gravel, slope was highly correlated with whole investigated soil properties which orderly as profile depth, salinity, sand, silt, clay, pH and lime (Table 6). On the other hand, wetness index was only correlated orderly with sand, profile depth, clay, silt and salinity (Table 6). The correlation between these three terrain parameters and soil attributes supports the hypothesis that the soil catena develops in response to the way water flows through and over the landscape. Individually, correlated terrain attributes accounted for about one-half of the variability of profile depth, salinity, sand and lime content.

Negative and positive correlations are found between profile depth with slope and wetness index, respectively, that deep and very deep profile depths are confined where slopes are less than 1.0 % and associated with areas that have wetness index more than 5.0. Soil salinity was negatively affected by steep slopes due to leaching process and positively by high wetness index associated with precipitations at downstream.

Table 3. Primary topographic features of Al-Shobeity watershed basin

Profile no.	Elevation m.A.S.L	Overall Slope, %	Aspect	Micro-Relief
1	12	0.5	N	Leveled
2	14	0.6	N	Leveled
3	18	0.6	NW	Slight M.R
4	22	0.8	NW	Slight M.R
5	27	0.7	NW	Moderate M.R
6	32	0.8	NW	Moderate M.R
7	36	0.8	N	Moderate M.R
8	42	0.9	N	Moderate M.R
9	44	1.8	NW	Moderate M.R
10	59	3.8	NW	Moderate M.R
11	61	5.2	NW	Strong M.R
12	68	1.5	NW	Strong M.R
13	73	1.0	N	Very Slight M.R
14	78	0.9	N	Leveled
15	12	0.3	N	Leveled
16	16	0.6	N	Leveled
17	18	1.0	NE	Slight M.R
18	23	0.2	N	Slight M.R
19	32	1.2	NW	Moderate M.R
20	37	0.9	N	Moderate M.R
21	42	0.9	N	Strong M.R
22	48	1.0	N	Moderate M.R
23	50	1.8	N	Moderate M.R
24	54	2.4	N	Strong M.R
25	57	3.8	NE	Strong M.R
26	62	6.2	NE	Strong M.R
27	69	2.5	NW	Moderate M.R
28	71	1.0	N	Slight M.R
29	72	0.5	N	Slight M.R
30	78	0.3	N	Leveled

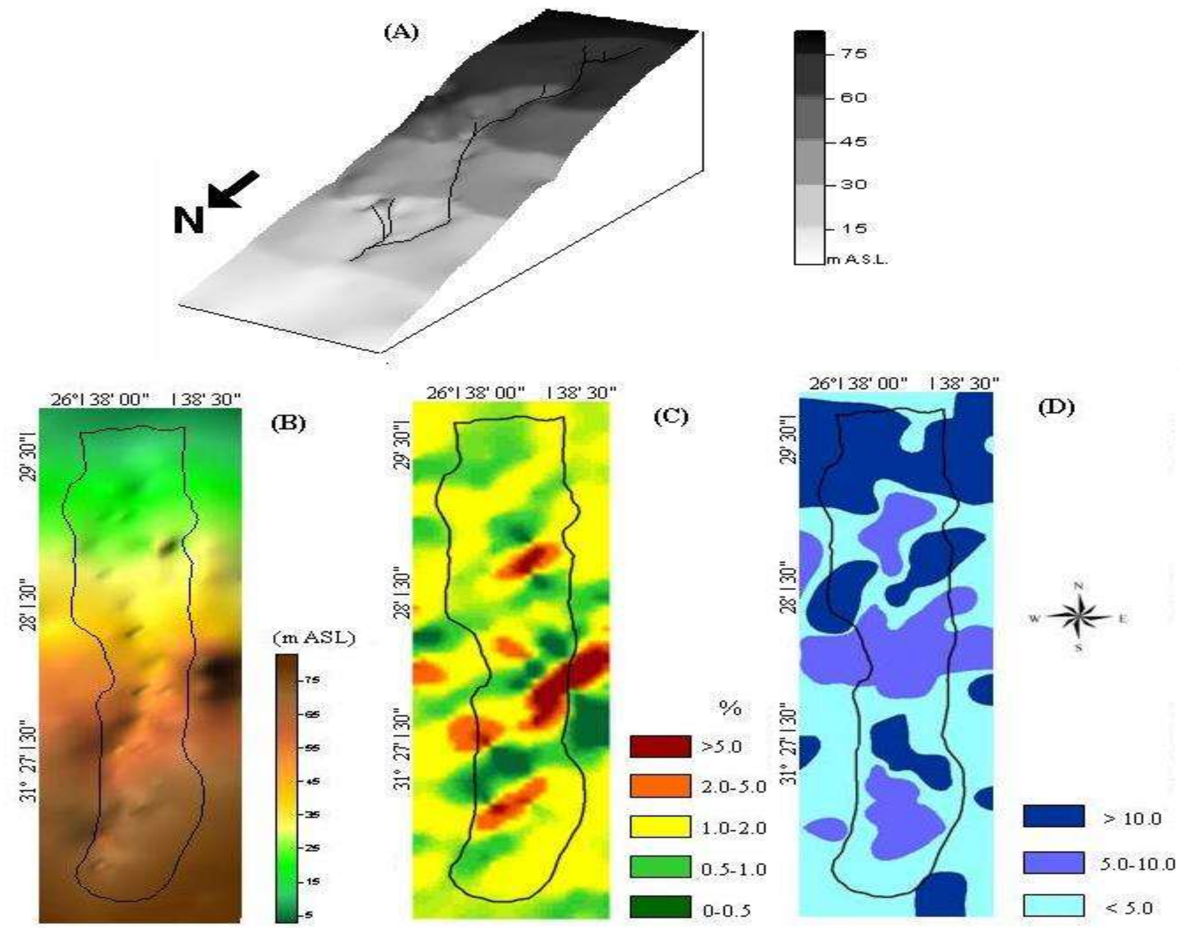
N = North NE = Northern east NW = Northern west M.R = Micro relief

Table 4. Slope classes and corresponding areas at Wadi Al-Shobeity

Class	Value	Area (Fed.)	Percent
Level	0.0-0.5 %	221	11.5
Nearly level	0.5-1.0 %	353	18.4
Gently slope	1.0-2.0 %	1014	52.8
Moderate slope	2.0-5.0 %	171	8.9
Sloppy	5.0-10.0 %	161	8.4

Table 5. Secondary terrain indices of Al-Shobeity watershed basin

Secondary Terrain Indices	Area (Fed.)	%
Wetness index classes		
(a) high runoff generation area	952	49.6
(b) low runoff generation area	472	24.6
(c) zones of saturation	495	**25.8**
Sediment transport index		
(a) low (0-250)	1584.00	82.5
(b) high (250-500)	336.00	**17.5**
Stream power index		
(a) low (0-10000)	1505.28	78.4
(b) high (10000-25000)	414.72	**21.6**



Map 4. Topographyic attributes and indices of Al- Shobeity basin: A- Terrain 3D, B- DEM, C- Slope, D- Wetness index.

Table 6. Correlation matrix between terrain and soil attributes at Al-Shobeity basin

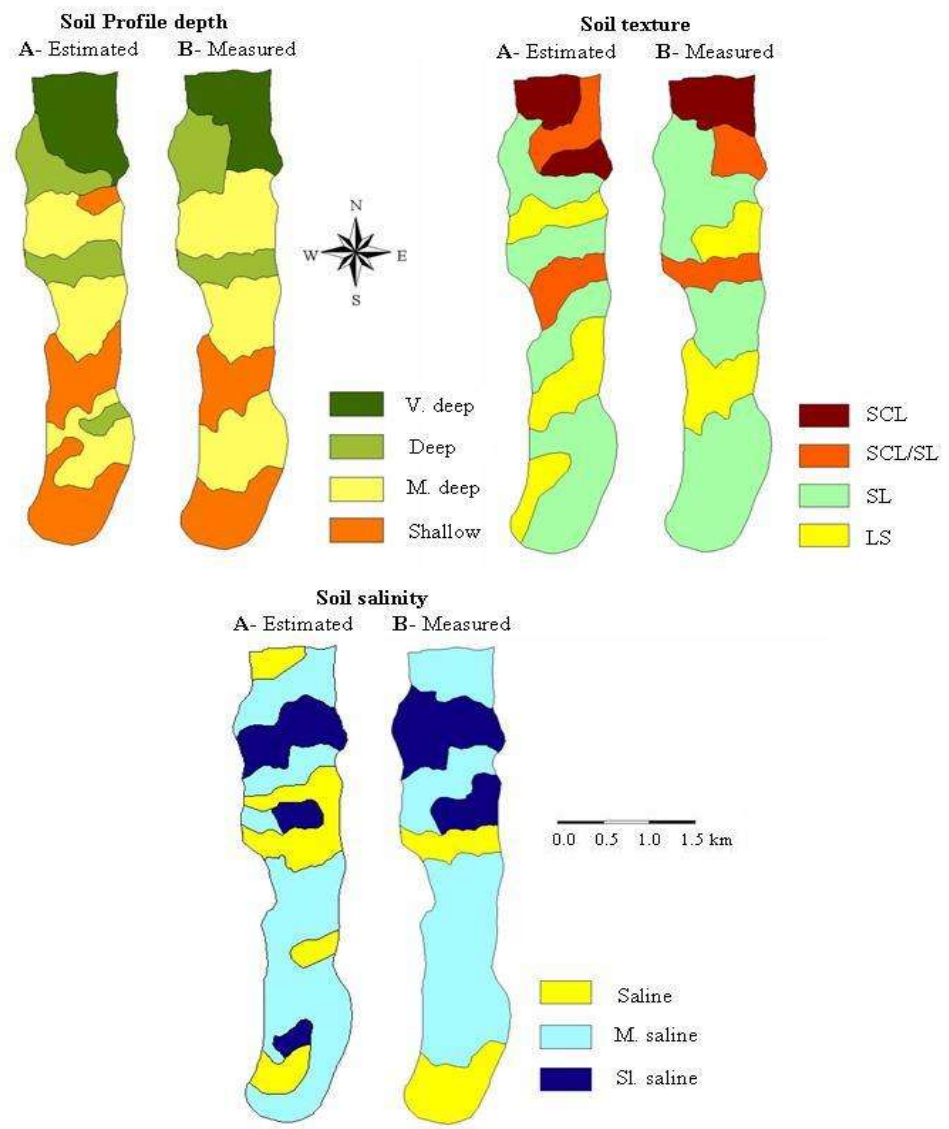
Prf D												
-0.58	**Grav**											
-0.22	0.06	**pH**										
0.35	0.46	0.88	**Lime**									
-0.52	0.28	0.45	0.35	**Sal**								
0.68	0.07	-0.25	0.44	0.65	**Clay**							
-0.16	0.10	-0.35	0.36	0.28	-0.52	**Silt**						
0.44	0.45	0.48	-0.54	-0.74	-0.74	-0.77	**Sand**					
-0.81	-0.22	**0.62**	**-0.58**	**-0.76**	**-0.65**	**-0.72**	**0.75**	**Slope**				
0.18	0.18	-0.45	0.22	0.32	0.12	0.18	-0.28	-0.30	**Asp**			
0.65	-0.25	-0.35	0.42	**0.52**	**0.62**	**0.60**	**-0.77**	-0.75	0.06	**Wet**		
-0.08	-0.22	0.28	-0.08	-0.17	0.43	-0.12	0.22	0.62	-0.25	0.65	**Str**	
-0.39	-0.42	0.44	-0.18	-0.24	0.48	-0.35	0.34	0.92	-0.32	0.54	0.88	**Sed**

Prf D = Profile depth Grav = Gravels
Sal = Salinity as EC Asp = Aspect
Wet = Wetness index Str = Stream power index
Sed = Sediment transport index

Saline soils occur mainly where the slopes are less than 2 % and where wetness index is more than 5.0. Spatial distribution of lime content does not follow wetness index while it was obviously negatively correlated with slope, where lime content is more than 30 % associated with areas that have slope degrees less than 2.0 %.

5- Estimation of soil properties:

The best combination of terrain variables for explaining the variations in measured soil attributes was found out using stepwise linear regression analysis. Regression equations were formulated using calculated intercepts and terrain attributes coefficients. Regression coefficients describe the slopes of linear regression between properties (Table 7). Only variables that improved the regression at 0.01 level were included. Slope and wetness index were brought into regression at three steps. Regression equations were then used to predict the spatial distribution of profile depth, sand, silt, clay and salinity. Soil texture was idenified at each grid node according to texture triangle (Page *et al*., 1982). The actual and estimated values of soil attributes were compared as seen in map (5).



Map 5. Comparizon between (A) estimated and (B) measured spatial distributions of soil profile depth, soil texture and soil salinity at Al- Shobeity Watershed basin.

Table 7. Regression equations relating measured soil properties with significant terrain attributes at 0.01 level

Soil prop. / Terrain attr.	Intercept	Slope	Wetness index	Stream power index	R^2
Profile depth (cm)	0.08	-0.08 (1) *	0.05 (2)	0.04 (3)	0.68
Salinity (dSm^{-1})	3.14	-0.82 (1)	-	0.75 (2)	0.48
Sand (%)	5.72	1.14 (1)	1.08 (2)	–	0.55
Clay (%)	7.86	-	0.54 (1)	-	0.40

* Numbers between parentheses indicate the order in which the variable brought into regression

The regression analysis reasonably succeeded in explaining from 40 to 68 % of the measured soil attributes variability. High degree of similarity was achieved for the soil spatial distributions between measured properties and estimated ones using terrain measurements as seen in map (5). Terrain attributes succeed in prediction of profile depth, soil texture and soil salinity over 89, 84 and 75 %, respectively, of the sampled locations, which could be considered quite good. That terrain–based technique succeeded in achieving the inner variation of soil properties. Traditionally, soil studies have not incorporate information about local process like solute and sediment transport according to hydrology, hence have not been able to predict soil spatial variability within a soil map unit. Estimation of soil attributes using their correlations with terrain features may be applied as a first step to guide sampling and model development in unmapped areas. Results presented in this study emphasized on that significant impact of catchment basin hydrology on soil attributes re-distribution, therefore on crop production potential. Surface soil properties are most modified by land management, so lower horizons are most affected by topographic attributes. High resolution DEM may be hermeneutic for characterizing microscale variations in the terrain.

The standard errors (SE) of prediction associated with soil properties estimation were 0.22, 0.31 and 0.26 for soil depth, texture, and salinity, respectively. These low values indicate reasonable results of similarity between actual and estimated data.

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الملخص العربي

التحليل الطبوغرافى للأرض كمعيار لصفات التربة بوادى الشبيطى، الساحل الشمالى الغربى، مصر

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لقد تطور علم البيدولوجى فى الآونة الأخيرة تطورا ملحوظا حيث إشتملت طرق الدراسة على معايير كمية دقيقة لتوصيف التوزيع المكانى لصفات وخواص التربة والتى لا تتوزع عشوائيا بل إنها تتبع فى ذلك نمطا مميزا وفقا لعوامل وعمليات تكوين الأراضى. وتعتمد هذه الدراسة على أن التغير المتسلسل فى صفات التربة والذى يحدث بأراضى أحواض التجميع المائى يكون إستجابة لحركة صرف مياة الأمطار سواء كان ذلك على سطح التربة أو بداخلها. وتهدف تلك الدراسة إلى توصيف توزيع خصائص التربة بناءا على إرتباطها بالصفات الطبوغرافية نتيجة تأثير الأخيرة على حركة التدفق المائى ومن ثم على إعادة توزيع الأملاح والرواسب. أختيرت منطقة الدراسة والتى تمتد على مساحة 1920 فدان لتمثل حوض التجميع المائى لوادى الشبيطى أحد مجارى الصرف المائى والذى يبعد عن مطروح بـ 68 كم غربا. تم حصر منطقة الدراسة كمتسلسلة أرضية بإستخدام 30 قطاع أرضى ممثل على إمتداد خطيى قطع عرضيين للوحدات الجيومورفولوجية الممثلة للمنطقة بدءا من الهضبة الجيرية الجنوبية حتى نهاية السهل الساحلى الشمالى لتمثيل كافة الإختلافات الطبوغرافية بها. وبناءا على التحليل المعملى أمكن تمييز عدد ثمان وحدات أرضية تباينت فيما بينها فى صفات عمق القطاع الأرضى والقوام والملوحة. حيث تبين أن 59.7% من المساحة المدروسة ذات قطاع أرضى متوسط العمق بينما شغلت التربة العميقة وشديدة العمق 21.6 % من إجمالى المساحة. ساد المنطقة قوام التربة الطمى الرملى والطمى الطينى الرملى على 88.4 % من المساحة المدروسة. معظم المنطقة تعد هينة إلى متوسطة الملوحة بينما إنحصرت المواقع المتأثرة بالملوحة على مساحة 26.7%. تم إنشاء النموذج الرقمى للإرتفاعات لحوض التجميع المائى للوادى بإستخدام نظام شبكى منتظم محدد الإحداثيات أبعاده 100م، وعند مواقع التقاطع بالشبكة تم حساب الصفات الطبوغرافية الأولية والتى تشمل الميل- الهيئة- مساحة الحصاد المائى-مسار التدفق الأكبر- تقوس سطح التربة. كما تم حساب الأدلة الطبوغرافية الثانوية والتى تربط أسباب تكوين التربة بأنماط توزيع صفاتها، والتى تشمل دليل الإبتلال wetind – دليل تدفق المياة strind– دليل حركة الرواسب sedind، مع رسم خرائط التوزيع المكانى لكل دليل بحوض التجميع المائى. أوضحت النتائج أن الإرتفاعات بحوض وادى الشبيطى إنحدرت من 80 إلى 5 م فوق مستوى البحر، مما نشأ عنه ميول سطحية معظمها شمالية تراوحت ما بين 0.3 -6.2%، حيث صنف ميل سطح الأرض معها إلى خمسة أقسام ما بين المستوى والمائل مع سيادة السطوح ذات الميل الهين(1-2%) على مساحة 52.8% من المنطقة وإنحصار السطوح المائلة(5-10%) على 8.4% من إجمالى المساحة. قسمت المنطقة بناءا على قيم دليل الإبتلال wetind لثلاث أقسام معبرة عن تشبع التربة بالماء حيث صنف 25.8% من إجمالى المساحة "كمناطق تشبع" بينما سادت مناطق "التدفق السطحى المرتفع" باقى المنطقة على 49.6%. من ناحية أخرى إنخفضت قيم دليلى حركة الرواسب sedind وقوة التدفق strind بالمنطقة المدروسة حيث بلغا قيما معنوية فقط على 17.5% و21.6% من إجمالى المساحة على الترتيب. مصفوفة معاملات الإرتباط بين الصفات الطبوغرافية والأرضية أوضحت أن الميل كمعيار طبوغرافى أولى هو الأكثر إرتباطا بتوزيع صفات عمق التربة- الملوحة- الرمل- السلت- الطين- تفاعل التربة- الجير، على الترتيب، حيث تراوح معامل الإرتباط ما بين 0.58 -0.81. بينما كان دليل الإبتلال كمعيار طبوغرافى ثانوى هو الأعلى إرتباطا مع صفات الرمل – عمق التربة- الطين- السلت- الملوحة، على الترتيب، حيث تراوح معامل الإرتباط ما بين 0.52 – 0.77. وأوضحت النتائج أيضا أن التربة العميقة أو الشديدة العمق لا تتكون بالمنطقة إلا عندما ينخفض الميل عن 1 % ويزيد دليل الإبتلال عن 5. كما أن التربة الملحية لا تتكون إلا عن ميول أقل من 2% ودليل إبتلال أكبر من 5. أستخدم الإرتداد الخطى متعدد المراحل لحساب معادلات إرتباط الصفات الطبوغرافية بالأرضية إحصائيا حيث أكدت الدراسة على وجود إرتباط معنوى بينهما عند

مستوى معنوية 0.01 نظرا لإرتفاع معامل الإرتداد ليبلغ 0.68- 0.48- 0.55- 0.40 على الترتيب لصفات عمق قطاع التربة- الملوحة- نسبة الرمل- نسبة الطين. ثم أستخدمت معادلات الإرتداد لتقدير خصائص عمق التربة والقوام والملوحة بدلالة الصفات الطبوغرافية مع رسم خرائط توزيعاتها مكانيا. قورنت تلك الصفات المقدرة للتربة بالقيم الحقيقية حيث أكدت الدراسة على أن هناك تقارب كبير فى التوزيع المكانى بين وحدات التربة المقدرة والحقيقية تم تأكيده كميا من خلال إنخفاض قيم الخطأ العيارى للتقدير، إضافة لزيادة قدر التفاصيل الجديدة والتى أدرجت بداخل وحدات التربة الأصلية. وتأتى أهمية البحث التطبيقية فى محاولة إستغلال إرتباط صفات التربة بطبوغرافية السطح فى تحديد تغيرات صفات التربة بداخل كل وحدة أرضية متجانسة جاءت بخريطة التربة التقليدية للمنطقة المدروسة، وبالتالى زيادة درجة إيضاح تفاصيل التوزيع المكانى لصفات التربة والذى يتحقق معه أصدق تمثيل للإختلافات الأرضية تزامنا مع إستهلاك أقل وقت وجهد وتكاليف مصاحبة لعملية الحصر.