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Incorporate the Fertility Capability Classification and Geo-informatics for Assessing Soil: A Case Study on Some Soils of Sohag Governorate, Egypt

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ABSTRACT

Soil, as a natural and nonrenewable resource become the most fragile ecosystem due to long-term cultivation by human being. The knowledge and understanding the parameters that determine the quality of agricultural soils can improve their management of soil resources. Geo-informatics techniques have emerged for the assessment, mapping and modelling of various soil resources. Hence, an attempt has made to study the soils of Sohag Governorate and generate fertility capability classification (FCC) map using geo-informatics. Different remote sensing data such as Landsat 9 imageries and ASTER sensor integrated. Consequently, representative soil profiles chosen and samples collected for analyzing. The results indicated that the main landforms observed were Nile Alluvium (NA), Low recent river terraces (LR), High recent river terraces (HR) and Wadi Bottom (WB). Soil fertility limitations and condition modifiers characterizing different units were identified. The fertility of the NA and LR soils was good with fewer limitations. Whereas, both HR and WB soils have many limitations that render them under either poor or very poor fertility capability. Generally, this information is valuable for decision-makers and land managers to make informed decisions about soil conservation and management.

Keywords: Geoinformatics, Fertility capability classification, Landforms.

INTRODUCTION

The study area:

The study area covers a part (about 2989.1 km^2) of Sohag governorate, Egypt which extending from the northern edge of Qena Governorate at latitude 26º07′ N to the southern edge of Assiut Governorate at latitude 26°57′ N. It is bounded between longitudes 31°20′ and 32°14′ E (Fig. 1). The study area belongs to the arid region of North Africa which is generally characterized by hot summer and mild winter with low rainfall. Air temperature ranges between 36.5°C (summer) and 15.5°C (Winter), relative humidity ranges between 51% and 61% (Winter), 33% and 41% (Spring), and 35% and 42% (Summer). Rainfall is generally rare and randomly precipitated over the area.

Hydrologically, the River Nile, irrigation canals, and drains represent surface water of Sohag area. The Quaternary aquifer system in the study area is formed by the alluvial deposits of the Nile and consists of two layers having distinct hydraulic properties. The upper layer is the clay–silt member, which has low horizontal and vertical permeability. The lower layer, the graded sand member, forms the main aquifer having high horizontal and vertical permeability (MPWWR 1988).

Soils in the study area include soils of the old cultivated lands, newly reclaimed lands and barren lands. The soils of the cultivated lands include clay, sandy loam, loam and sandy clay. While soils of the newly reclaimed lands include Sandy clay, sandy loam, sandy clay loam, clay loam, sandy and clay (this may be due to the addition of alluvium soils at different amounts on the surface of new reclaimed soils to enhance their characters). Finally, the sandy and sandy loam were found in barren lands (Mustafa, 2023). Soil conditions in the study area facilitate the transport of contaminants through the soil profile, which affects groundwater quality.

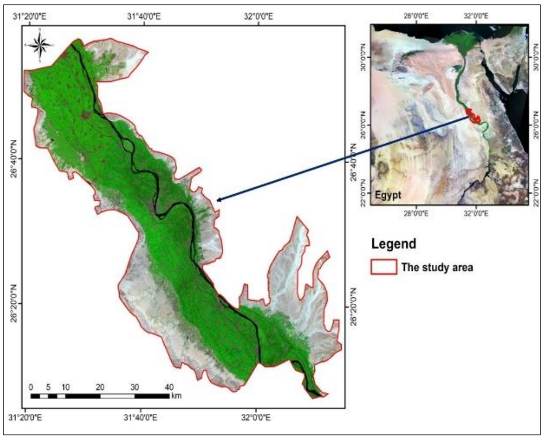

Fig. 1. Location map of the studied area

Agriculture represents the base of economy of Sohag area. The entire Nile Valley surface area is mainly used for agricultural activities except areas occupied by settlement. The edges of the valley on the east and west flanks are marked by new cultivated fringes. Crops are cultivated in a 2- or 3-year crop rotation including winter, summer, and nilotic (autumn) crops. Irrigation water is applied by the traditional flooding method (basin irrigation) which occurs at a frequency of two and three times a month.

Fertility Capability Classification (FCC):

Soil is the most valuable natural resource for any nation and the awareness about soil resource properties is a precondition for sustainable agriculture. Soil taxonomy systems emphasis on subsurface than on topsoil characteristics and place less emphasis on soil fertility. Hence, FCC system has recently proposed. This system proposed by Buol et al. (1975) and modified by Sanchez et al. (1982) was for further classification of landforms. This system consists of various factors viz. type,

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substrata type, physical, chemical properties which affect the interrelation between soil, water and plant. Additionally, the FCC system utilized for identifying soil fertility technical problems and the proper solutions to improve soil fertility. It is a technical system of grouping soils with similar constrains in terms of nutrient supply capacity of the soils.

For any particular soil, the FCC is presented as a code (such as Sek, a soil that is sandy for topsoil and subsoil, having high leaching potential and low nutrient reserves). The fertility constraints are high leaching potential (e), and low nutrient reserves (k). The interpretation of the code provides information for guiding farmers in choosing the right practices for the classified soil. This permit to utilize FCC system as the fundamental for classifying soils and suggesting suitable soil management practices. Geo-informatics are modern tools that provide information on variation over time essential for environmental monitoring and change detection, as they also help in the reduction of conventional time-consuming and expensive field sampling methods, which is the traditional method of monitoring and assessment. Yakubu et al. (2012) identified appropriate fertility management strategies for the soils in okoto-Rima Flood Plain, Nigeria for productive and sustainable agricultural landuse. Results indicated that three FCC dominate the study area: (i) Lgm-Loamy soils low in organic matter with gleying limitations (ii) Lghm Loamy soils, low in organic matter and with gleying and pH limitation (iii) Sgm Sandy soils low in organic matter and with gleying limitations. Also, Tabi et al. (2013) utilized the FCC system for rice production in Cameroon lowlands and concluded that the soil fertility limitations characterizing lowland rice producing areas in Cameroon were: Fe- and Al-toxicities (a), low nutrient capital reserves (k), high leaching potential (e), and micronutrient deficiencies (Fe and Zn). The lowland soils were classified as: Lagk, Cagk, Laegk, Cbgm, Caeg, Lbg, Lgk, Cgv, LCg and Cgv, which reflect these limitations.

Mustafa (2016) studied the some soils of the Eastern Desert Part of Sohag Governorate and map them based on the fertility capability classification (FCC) using remote sensing and GIS. Based on his results, the major landforms of the studied area were described as Wadi Bottom (WB), Bajada (B), Alluvial Fans (AF), Tableland (T), Gently Undulating Sand Sheet (GUS) and Undulating Sand Sheet (US). The type, substrata type and condition modifiers were also identified for each landform. The main condition modifiers of the study area were texture (S), low CEC (e), K deficiency (k), calcareous (b), salinity (s), dry condition (d), gravels (r) and low organic matter (m). Relevant FCC units were assigned to various landforms based on the type, substrata type and condition modifiers. A utility map was prepared using GIS with the FCC units, their limitations and extent distribution. Thus, the current study aims to classify some soils of Sohag Governorate based on FCC using geo-informatics technologies.

MATERIALS AND METHODS

Satellite images Data

In the current study, the digital data of geo-coded cloud free of Landsat 9 satellite images of 2022 were downloaded from http://glcf.umd.edu/data/landsat/. In addition, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data was used to prepare a Digital elevation model (DEM) of the study area with a spatial resolution of 15 m following the procedure adopted by Abrams (2010). The ground control points for the geometrical correction of the digital elevation model (DEM) obtained using a GPS. This DEM has used to generate topographical features in the present study.

Methodology

The methodology adopted in the study is discussed below:

Pre- processing of Remote sensing data:

Essential steps must do before digital image processing. This includes the generation of false color composite images, mosaicking of the three images and sub image extraction through on screen digitization of the area of interest (AOI) and masking out using subset module of ENVI software (ver.4.8).

Delineating of various landforms:

The spatial resolution of the used Landsat 9 was enhanced through the data merge process. This process commonly used to enhance the spatial resolution of multi-spectral datasets using higher spatial resolution panchromatic data resulting in multispectral data with high spatial resolution (15 m). The landforms map generated from the Shuttle Radar Topography Mission (SRTM) having 30 m spatial resolution and enhanced Landsat images using the ENVI 4.8 software (Dobos et al., 2002). In addition, visual image interpretation elements were used for gathering information about the terrain. Additionally, The Landsat and SRTM data utilized to enhance the visualization topographic features. Consequently, the landform units were defined and classified. The final geomorphologic map was finalized through field observations.

Field work and samples collection:

In order to gather in-depth knowledge about the soil patterns, landforms, and landscape characteristics, a quick reconnaissance survey was conducted. A total of 34 representative soil profiles (shown in Fig.2) were selected and exposed for morphological examination following the procedures outlined in the Soil Survey Manual (FAO, 2006). Soil samples were collected and prepared for analysis after examination. The location of each profile was recorded using a handheld GPS device. The Legend of the physiographic map of the studied area is presented in table (1).

Table 1. Legend of the physiographic map of the studied area

Physiographic unit	Land use	Profiles	Map unit	Area* km^2	%
Nile Alluvium	Cultivated	1,5,6,9,12,14,17,18 .19,22,24,28	NA	2021.1	70
Low recent river terraces	Cultivated	2,3,4,7,10,11,13,15 ,20,23,25,27	LR	346.5	12
High recent river terraces	Cultivated	8,16,21,26,29	HR	231.0	8
Wadi bottom	Barren	30,31,32,33,34	WB	288.7	10
Total				2887.3	100

*** The area excluding water bodies**

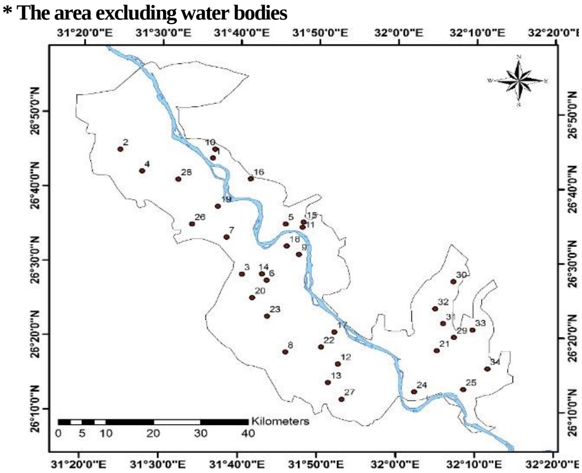

Fig. 2. Spatial distribution of the representative soil profiles.

Soil analysis and classification:

The collected soil samples were analyzed for their properties such as: Particle size distribution (Piper, 1950); using the sodium hexametaphosphate for dispersion in case of calcareous soils collected from high recent river terraces and Wadi bottom soils (USSL Staff, 1954), calcium carbonate, cation exchange capacity (CEC) and exchangeable sodium (Black, 1982); (ECe), soil pH, organic matter content (Jackson, 1973)

RESULTS AND DISCUSSION

Land use / land cover (LU/LC) of the study area:

The main LU/LC found in the study area were water bodies including Nile River, canals, drainage patterns and waste water treatment plants; desert lands; cultivated lands and urban areas. The cultivated lands account about 60.7 % of total geographic area (TGA) and include the old cultivated lands in the Nile Valley and other lands under reclamation. Whereas, approximately 23.6 % of total area occupied by desert lands. Whereas, urban and rural residential, services, commercial, industrial, and roads represented 12.3 % of TGA. Finally, about 3.4 % of TGA was considered as water bodies (Table 2) and (Fig. 3).

Table 2. Land use / land cover of the studied area.

Land use	Areas for the year 2022	
	km^2	%
Water bodies	101.8	3.4
Desert lands	703.8	23.6
Cultivated lands	1814.5	60.7
Urban Areas	369.0	12.3
Total	2989.1	100.0

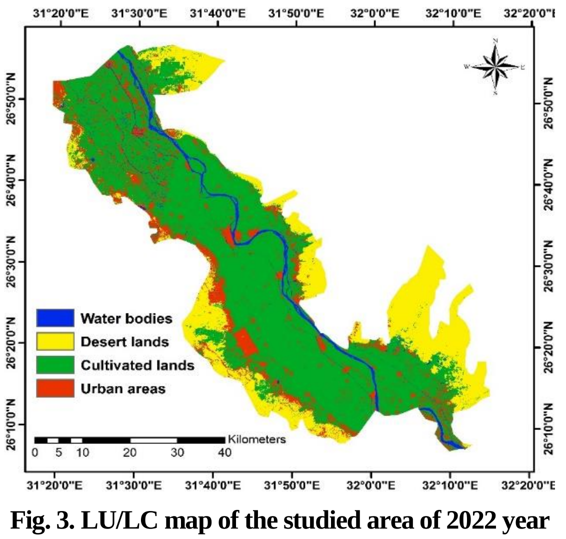

Fig. 3. LU/LC map of the studied area of 2022 year

Map units' description:

The soil attributes of the mapping units are presented in Table (2). In addition, the DEM and slope maps (Figs 4 and 5) generated and incorporated with field observations for defining various physiographic units occurring in the studied area. The results indicated that, there were four physiographic units in the area under studied (Fig. 6) viz. Nile Alluvium (NA), Low recent river terraces (LR), High recent river terraces (HR) and Wadi bottom (WB). The main characteristics of these units will be discussed.

Nile Alluvium (NA):

The total area of was about 2021.1 km^2 (70%) and are represented by soil profiles 1, 5, 6,9,12,14,17,18.19,22,24 and 28. In this landscape, the surface was very gently sloping and it is well drained (FAO, 2006). The following soil characteristics range as follows: soil depth (100 to 150 cm) except profile 24, which have depth of 70 cm, soil salinity (0.26 to 1.98 dS m^{-1}), ESP % (1.13 to 46.93%), and $CaCO_3$ content (0.53 to 4.96%). These soils are mildly to moderately alkaline and data show the values of pH ranged from 7.44 to 8.01.

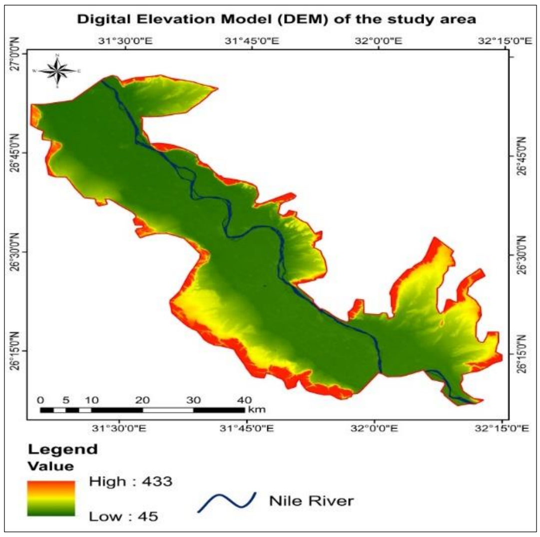

Fig. 4. Digital elevation model map of the studied area

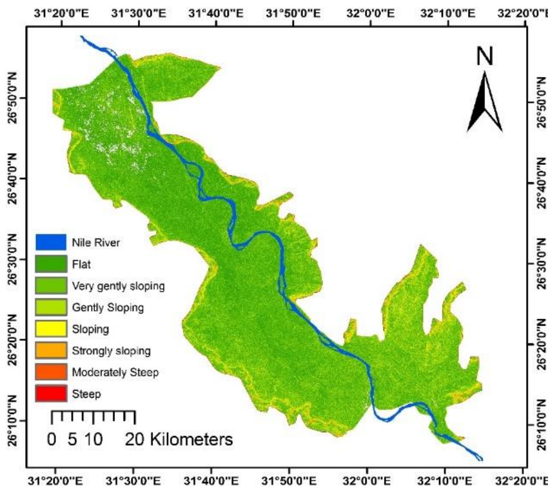

Fig. 5. Slope map of the studied area

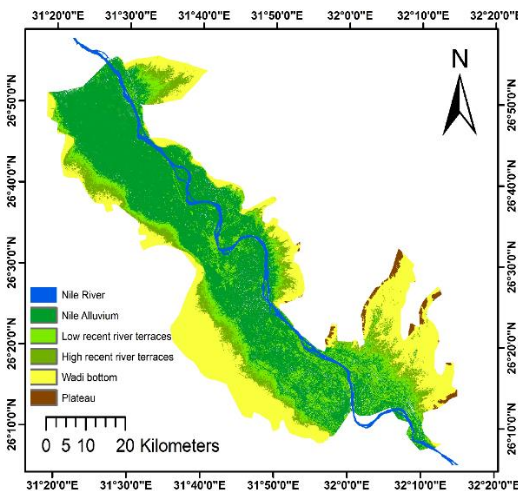

Fig. 6. Physiographic map of the study area

Low recent river terraces (LR):

This unit occupies an area of about 346.5 km^2 (12 %). The represented profiles were profiles No. 2,3,4,7, 10,11, 13,15,20,23,25 and 27. Based on FAO (2006), the slope gradient classes of this unit characterized by nearly level and it is well drained. The depth of soil profiles ranged from 100 to 120 cm. The soil texture varied from coarse sand to clay. The EC values ranged from 0.31 to 3.65 dS m^{-1}. The $CaCO_3$ content varied from 2.21 to 30.55%. The Values of pH were mildly to moderately alkaline except profiles No. 10 was strongly alkaline and has pH value of 8.54.

High recent river terraces (HR):

This unit occupies an area of approximately 231.0 km2 (8%). The represented profiles were profiles No. 8,16,21,26 and 29. The soil depths vary from 110 to 150 cm. The soil texture varied from sand to sandy loam. The EC values are moderately saline and ranged from 7.65 to 8.05 dS m^{-1}. The $CaCO_3$ content varied from 17.67 to 33.94%. The Values of pH ranged from 7.62 to 8.14.

Wadi bottom (WB):

This unit occupies an area of about 288.7 km^2 (10 %). The represented profiles are profiles No. 30, 31, 32, 33 and 34. The landscape is characterized by gently sloping. The vegetation cover is few, and present as small shrubs. The soils surface covered by desert pavement of different sizes. The profiles' depths were greater than 125 cm. The soil texture is sandy. The EC values were very strongly saline and ranged from 11.64 to 24.15 dS m^{-1}. The $CaCO_3$ content were very high and varied from 28.74 to 38.12%. The Values of pH are moderately alkaline and ranged from 8.11 to 8.32.

Fertility capability classification:

The obtained results (Tables 3, 4, 5 and 6) used for identifying the condition modifiers based on type and substrata type then FCC units were established (Table 7). The condition modifiers of the studied soils discussed hereunder:

Nile Alluvium (NA):

The main condition modifiers were dry condition (d), low OM (m), low nutrients reserves (k) for profile No. 12 and nitric (n) for profile No. 24 which has ESP greater than 15% (46.93 %). Hence, this unit was classified as Ldm, Ld, Lkdm, Cd, Cnd.

Low recent river terraces (LR):

There were some limitations related to this unit including texture (S), dry condition (d), low organic matter (m), low nutrients reserves (k), low CEC (e), calcareous (b) and nitric (n) for profiles No. 7, 10 and 25. Accordingly, The FCC units were CSdm, LSdm, Skdm, LSndm, LSnd, LSkd, Sekbdm, LSekbd, CSnd and LSekbdm.

Table 3. The main soil characteristics of the Nile Alluvium landform

Profile No.	1	5	6	9	12	14	17	18	19	22	24	28
1-Climate (c)												
Precipitation (mm)	0	0	0	0	0	0	0	0	0	0	0	0
Mean temp. ^{0}C	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
RH (%)	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
Actual sunshine (hrs)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
2-Soil physical charateristics												
Depth (cm)	120	100	110	100	150	115	110	110	110	100	70	115
Sand (%)	69.67	60.55	57.00	55.40	61.07	40.57	30.45	43.73	74.46	57.50	26.21	75.00
Silt (%)	15.54	13.35	12.50	10.60	20.87	15.61	38.73	31.18	14.03	29.60	27.86	13.17
Clay (%)	14.79	26.10	30.50	34.00	18.07	43.83	30.82	25.09	11.51	12.90	45.93	11.83
Texture	SL	SCL	SCL	SCL	SL	C	SCL	L	SL	SL	C	SL
3-Topography												
Slope (%)	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
4-Wet conditions												
Drainage	WD	WD	WD	WD	WD	WD	WD	WD	WD	WD	MD	WD
Flood duration (month)	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0
5-Fertility												
pH	7.65	7.61	8.21	8.14	7.82	7.88	7.64	7.88	8.01	7.44	7.62	7.96
TN (%)	0.04	0.04	0.05	0.06	0.04	0.05	0.05	0.06	0.04	0.11	0.05	0.04
OC (%)	0.43	0.31	0.49	0.61	0.29	0.55	0.46	0.60	0.38	1.46	0.58	0.32
Avai. P (mg/kg)	24.16	30.18	31.14	67.20	9.06	48.55	9.51	19.55	13.18	24.70	43.55	27.54
Exch. Na (cmol+/kg)	0.08	0.42	0.45	0.40	0.18	1.03	2.49	0.55	0.10	1.00	7.68	0.11
Exch. K (cmol+/kg)	0.27	0.37	0.31	0.26	0.09	0.40	0.25	0.27	0.30	0.31	0.29	0.31
Exch. Ca (cmol+/kg)	5.59	5.35	6.56	5.75	2.67	7.83	4.22	5.47	4.78	4.01	6.86	4.09
Exch. Mg (cmol+/kg)	1.31	1.74	1.47	1.32	0.41	1.60	1.55	1.80	1.33	1.42	3.11	1.40
CEC (cmol+/kg)	7.43	8.01	8.93	7.88	4.03	10.98	6.54	8.20	7.10	5.24	17.43	6.55
BS (%)	97.50	98.38	98.47	98.04	83.43	98.90	99.00	98.56	91.63	99.00	99.94	90.29
ESP (%)	1.13	5.33	5.01	4.98	5.02	9.43	14.73	6.75	1.41	12.58	46.93	1.50
Avai.Fe (mg/kg)	4.02	6.76	8.18	10.02	12.23	9.07	16.98	8.92	8.74	13.58	15.90	10.53
Avai.Mn (mg/kg)	5.16	10.38	4.98	7.22	7.62	8.66	10.02	8.47	5.20	9.27	14.59	6.60
Avai. Zn (mg/kg)	0.59	0.56	0.64	0.47	0.87	0.50	1.01	0.64	0.35	0.63	0.97	0.40
Avai.Cu (mg/kg)	0.31	2.88	2.81	2.06	2.75	3.55	3.76	3.21	0.58	3.22	3.82	1.30
ECe	0.26	0.96	0.61	0.55	1.98	0.89	0.68	0.30	0.28	0.46	0.89	0.32
$CaCO_3$ (%)	0.53	1.07	4.25	3.84	1.78	4.40	3.74	0.91	0.62	3.00	4.96	0.78

SL: sandy loam, SCL: sandy clay loam, C: clay, L: loam, , WD: Well drained, MD: moderately drained, F0: No flooding, BS: base saturation.

High recent river terraces (HR):

Fertility constraints of these soils related to coarse texture and consequently, low CEC, low nutrients reserves and low organic matter content. Hence, the draught constraint (d) was identified. The other modifiers are because of high calcium carbonates and high salinity. All these previous modifiers bring the soils under Sekbsdm fertility unit.

Wadi bottom (WB):

The r modifier in FCC identifies soils with layers having more than 10% gravel content by volume in the top 50 cm of the soil. Gravel reduces the available water content of soils, makes tillage difficult, and may damage equipment. Gravel is particularly widespread in the soils of this unit. In addition of all the above mentioned constrains that observed in HR unit, gravels were found in the profiles. So, the soils were fall under Sekbsdrm fertility unit.

Table 4. The main soil characteristics of the low recent river terraces landform

Profile No.	2	3	4	7	10	11	13	15	20	23	25	27
1-Climate (c)	Same as Nile Alluvium landform											
2-Soil physical charateristics												
Depth (cm)	115	110	100	110	120	100	110	110	115	120	112	100
Sand (%)	55.65	74.73	88.70	48.27	42.67	59.85	93.45	72.68	90.28	83.29	29.46	76.05
Silt (%)	7.86	13.00	5.80	22.77	29.33	11.65	4.95	10.50	4.61	9.83	21.59	8.75
Clay (%)	36.49	12.27	5.50	28.95	28.00	28.50	2.00	16.82	5.11	6.88	48.95	15.20
Texture	SC	SL	S	SCL	CL	SCL	S	SL	S	S	C	SL
3-Topography												
Slope (%)	2-4	1-2	2-4	1-2	2-4	2-4	1-2	1-2	1-2	2-4	2-4	1-2
4-Wet conditions												
Drainage	WD	WD	WD	WD	WD	WD	WD	WD	WD	WD	MD	WD
Flood duration (month)	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0	F0
5-Fertility												
pH	7.81	7.88	7.90	7.68	8.54	7.66	8.72	8.07	8.02	8.00	7.77	7.76
TN (%)	0.03	0.02	0.02	0.03	0.06	0.05	0.02	0.04	0.02	0.04	0.07	0.02
OC (%)	0.35	0.03	0.14	0.26	0.58	0.53	0.04	0.50	0.06	0.39	0.79	0.03
Avai. P (mg/kg)	18.75	7.91	40.68	46.00	31.79	30.84	15.43	63.39	5.51	4.39	76.83	0.33
Exch. Na (cmol+/kg)	0.68	0.32	0.17	4.07	1.91	0.45	0.14	0.20	0.13	0.20	4.49	0.45
Exch. K (cmol+/kg)	0.30	0.08	0.18	0.23	0.31	0.34	0.01	0.05	0.01	0.03	0.46	0.09
Exch. Ca (cmol+/kg)	5.99	2.77	3.41	3.58	8.19	6.12	1.36	2.59	1.60	2.42	6.34	4.32
Exch. Mg (cmol+/kg)	1.36	0.36	1.32	1.12	1.17	1.09	0.09	0.20	0.10	0.39	2.67	0.45
CEC (cmol+/kg)	8.44	3.60	5.19	9.16	11.72	8.42	1.73	2.89	1.94	2.52	18.05	3.63
BS (%)	98.65	98.14	98.10	98.18	98.76	95.03	92.79	99.00	95.55	99.00	77.31	99.00
ESP (%)	8.07	8.61	3.39	44.95	17.13	5.41	9.33	7.09	7.04	7.39	40.07	8.27
Avai.Fe (mg/kg)	7.47	2.64	2.46	12.99	11.13	4.43	3.48	4.08	2.88	3.10	16.68	2.14
Avai.Mn (mg/kg)	8.98	0.59	2.61	8.11	9.90	10.33	0.46	5.81	0.53	0.58	10.71	0.30
Avai. Zn (mg/kg)	0.56	0.27	0.28	0.65	0.55	0.58	0.23	0.74	0.26	0.26	0.61	0.13
Avai.Cu (mg/kg)	3.77	0.32	0.57	3.09	3.92	2.76	0.28	0.87	0.35	0.30	2.62	0.29
ECe	0.47	1.29	0.31	0.40	3.65	0.38	0.99	0.47	1.07	0.45	0.51	1.47
$CaCO_3$ (%)	4.77	19.65	10.59	3.72	4.91	2.21	31.35	20.66	30.55	21.13	3.00	18.87

SC: sandy clay, SL: sandy loam, S: sandy, SCL: sandy clay loam, CL: clay loam, S: sandy,C: clay, L: loam, WD: Well drained, MD: moderately drained, F0: No flooding, BS: base saturation.

Table 5. The main soil characteristics of the high recent river terraces landform

Profile No.	8	16	21	26	29
1-Climate (c)	Same as Nile Alluvium landform				
2-Soil physical charateristics					
Depth (cm)	150	110	115	115	115
Sand (%)	88.60	91.73	89.60	76.95	74.73
Silt (%)	4.93	3.41	4.30	8.65	13.00
Clay (%)	6.47	4.86	6.10	14.40	12.27
Texture	s	s	s	sl	sl
3-Topography					
Slope (%)	1-2	1-2	2-4	1-2	2-4
4-Wet conditions					
Drainage	WD	WD	WD	WD	WD
Flood duration (month)	F0	F0	F0	F0	F0
5-Fertility					
pH	7.70	8.05	7.65	7.65	7.88
TN (%)	0.04	0.02	0.05	0.02	0.02
OC (%)	0.41	0.08	0.45	0.03	0.03
Avai. P (mg/kg)	6.56	4.49	2.13	4.88	7.91
Exch. Na (cmol+/kg)	0.26	0.12	0.26	0.27	0.32
Exch. K (cmol+/kg)	0.11	0.04	0.04	0.03	0.08
Exch. Ca (cmol+/kg)	2.12	1.68	2.52	2.85	2.77
Exch. Mg (cmol+/kg)	0.59	0.24	0.27	0.19	0.36
CEC (cmol+/kg)	3.12	2.25	3.27	3.70	3.60
BS (%)	98.97	92.22	94.77	90.40	98.14
ESP (%)	8.15	5.36	7.86	7.92	8.61
Avai.Fe (mg/kg)	3.53	3.31	2.31	3.05	2.64
Avai.Mn (mg/kg)	0.69	0.40	0.31	0.36	0.59
Avai. Zn (mg/kg)	0.27	0.22	0.23	0.21	0.27
Avai.Cu (mg/kg)	0.39	0.32	0.30	0.32	0.32
ECe	7.7	8.05	7.65	7.65	7.88
$CaCO_3$ (%)	19.16	33.94	18.89	20.22	17.67

S: sandy, SL: sandy loam, WD: Well drained, F0: No flooding, BS: base saturation.

Table 6. The main soil characteristics of the wadi bottom landform

Profile No.	30	31	32	33	34
1-Climate (c)	Same as Nile Alluvium landform				
2-Soil physical charateristics					
Depth (cm)	150	155	135	125	145
Gravels (%)	20	15	32	25	17
Sand (%)	87.27	92.0	85.15	78.80	90.0
Silt (%)	3.73	4.2	4.65	6.12	2.0
Clay (%)	9.00	3.8	10.20	15.08	8.0
Texture	ls	s	ls	ls	s
3-Topography					
Slope (%)	2-4	2-4	2-4	2-4	2-4
4-Wet conditions					
Drainage	WD	WD	WD	WD	WD
Flood duration (month)	F0	F0	F0	F0	F0
5-Fertility					
pH	8.21	8.11	8.32	8.14	8.17
TN (%)	0.04	0.03	0.05	0.02	0.02
OC (%)	0.01	0.02	0.01	0.01	0.01
Avai. P (mg/kg)	5.56	2.89	3.13	4.15	6.87
Exch. Na (cmol+/kg)	0.34	0.42	0.26	0.27	0.41
Exch. K (cmol+/kg)	0.13	0.14	0.04	0.17	0.19
Exch. Ca (cmol+/kg)	2.71	1.68	2.52	2.85	2.82
Exch. Mg (cmol+/kg)	0.64	0.47	0.27	0.47	0.37
CEC (cmol+/kg)	3.92	2.74	3.17	3.85	3.86
BS (%)	97.45	98.91	97.48	97.66	98.19
ESP (%)	8.67	15.33	8.20	7.01	10.62
Avai.Fe (mg/kg)	0.47	0.55	0.27	0.29	0.45
Avai.Mn (mg/kg)	0.21	0.32	0.33	0.31	0.59
Avai. Zn (mg/kg)	2.31	2.88	1.23	1.97	2.14
Avai.Cu (mg/kg)	0.05	0.03	0.14	0.18	0.15
ECe	19.23	11.64	20.41	24.15	17.55
$CaCO_3$ (%)	29.25	37.87	28.74	35.57	38.12

S: sandy, LS: loamy sand, WD: Well drained, F0: No flooding, BS: base saturation.

Table 7. The condition modifiers and FCC units

Map unit	Profile No.	Type	Substrata Type	Condition modifiers									FCC unit
				e	k	b	s	n	d+	r+	SR	m	
NA	1	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
	5	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
	6	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
	9	L	L	-	-	-	_	-	+	_	-	-	Ld(1-2%)
	12	L	L	-	+	-	_	-	+	_	-	+	Lkdm(1-2%)
	14	C	C	-	-	-	_	-	+	_	-	-	Cd(1-2%)
	17	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
	18	L	L	-	-	-	_	-	+	_	-	-	Ld(1-2%)
	19	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
	22	L	L	-	-	-	_	-	+	_	-	-	Ld(1-2%)
	24	C	C	-	-	-	_	+	+	_	-	-	Cnd(1-2%)
	28	L	L	-	-	-	_	-	+	_	-	+	Ldm(1-2%)
LR	2	C	S	-	-		_	-	+	_	-	+	CSdm(2-4%)
	3	L	S	+	+	+	_	-	+	_	-	+	LSdm(1-2%)
	4	S	S	-	+	-	_	-	+	_	-	+	Skdm(2-4%)
	7	L	S	-	-	-	_	+	+	_	-	+	LSndm(1-2%)
	10	L	S	-	_	-	_	+	+	_	-	_	LSnd(2-4%)
	11	L	S	-	+	-	_	-	+	_	-	_	LSkd(2-4%)
	13	S	S	+	+	+	_	-	+	_	-	+	Sekbdm(1-2%)
	15	L	S	+	+	+	_	-	+	_	-	_	LSekbd(1-2%)
	20	S	S	+	+	+	_	-	+	_	-	+	Sekbdm(1-2%)
	23	S	S	+	+	+	_	-	+	_	-	+	Sekbdm(2-4%)
	25	C	S	-	-	-	_	+	+	_	-	_	CSnd(2-4%)
	27	L	S	+	+	+	_	-	+	_	-	+	LSekbdm(1-2%)
HR	8	S	S	+	+	+	+	_	+	_	-	+	Sekbsdm(1-2%)
	16	S	S	+	+	+	+	_	+	_	-	+	Sekbsdm(1-2%)
	21	S	S	+	+	+	+	_	+	_	-	+	Sekbsdm(2-4%)
	26	S	S	+	+	+	+	_	+	_	-	+	Sekbsdm(1-2%)
	29	S	S	+	+	+	+	_	+	_	-	+	Sekbsdm(2-4%)
WB	30	S	S	+	+	+	+	_	+	+	_	+	Sekbsdrm(2-4%)
	31	S	S	+	+	+	+		+	+	_	+	Sekbsdrm(2-4%)
	32	S	S	+	+	+	+	_	+	+	_	+	Sekbsdrm(2-4%)
	33	S	S	+	+	+	+		+	+	_	+	Sekbsdrm(2-4%)
	34	S	S	+	+	+	+	_	+	+	_	+	Sekbsdrm(2-4%)

S:sandy, e:low CEC, k:low nutrient reserves, b: calcareous, s: salinity, n^-: nitric, d^+: dry soil moisture condition, r^+: gravels, SR: erosion, m: low organic matter and %: slope.

Table 8. FCC units interpretation

Map unit	FCC unit	Description
NA	Ldm	Loam surface and subsurface soils with dry conditions and low in SOC.
	Ld	Loam surface and subsurface soils with dry conditions.
	Lkdm	Loam surface and subsurface soils with dry conditions, having low SOC and nutrients reserves.
	Cd	Clay surface and subsurface soils with dry conditions.
	Cnd	Clay surface and subsurface soils having ESP values greater than 15 % with dry conditions.
LR	CSdm	Clay surface and sandy subsurface soils with dry conditions and low in SOC.
	LSdm	Loam surface and sandy subsurface soils with dry conditions and low in SOC.
	Skdm	Sandy surface and subsurface soils having low SOC and nutrients reserves with dry conditions.
	LSndm	Loam surface and sandy subsurface soils having ESP values greater than 15 % with dry conditions and low in SOC.
	LSnd	Loam surface and sandy subsurface soils having ESP values greater than 15 % with dry conditions.
	LSkd	Loam surface and sandy subsurface soils deficient in nutrients reserves with dry conditions.
	Sekbdm	Sandy surface and subsurface soils having low SOC, nutrients reserves and CEC with high $CaCO_3$ content, dry conditions.
	LSekbd	Loam surface and sandy subsurface soils having low SOC, nutrients reserves and CEC with high $CaCO_3$ content and dry conditions
	CSnd	Clay surface and sandy subsurface soils having ESP values greater than 15 % with dry conditions.
	LSekbdm	Loam surface and Sandy subsurface soils having low SOC, nutrients reserves and CEC with high $CaCO_3$ content, dry conditions.
HR	Sekbsdm	Sandy surface and subsurface soils having low SOC, nutrients reserves and CEC with high $CaCO_3$ content, high salinity, dry conditions.
WB	Sekbsdrm	Sandy surface and subsurface soils having low SOC, nutrients reserves and CEC with high $CaCO_3$ content, high salinity, dry conditions, gravels content..

CONCLUSION

Based on the findings, the main landforms observed in the study area were categorized as Nile Alluvium (NA), Low recent river terraces (LR), High recent river terraces (HR), and Wadi Bottom (WB). Soil fertility limitations and condition modifiers characterizing different units were identified. Generally, the fertility of the NA and LR soils was good with fewer limitations. Whereas, both HR and WB soils have many limitations that render them under either poor or very poor fertility capability.

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دمج تصنيف القدرة الخصوبة والجيومعلوماتية لتقييم التربة: حالة دراسة عن بعض أنواع تربة محافظة سوهاج ، مصر

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الملخص

تعتبر التربة من أحد أهم الموارد الطبيعية الغير متجددة والتى يمكن ان تجعل النظام البيئى هش بسبب الاستخدام المستمر والمتزايد لذا نحتاج إلي وضع قاعدة بيانات توضح أهم المعايير التى تحدد جودة التربة الزراعية مما يمكن من إستغلالها الإستغلال الأمثل . وتعتبرتقنية الجيومعلوماتية ورسم الخرائط ونمذجة التربة من أهم الطرق المستخدمة في دراسة التربة والمشكلات التي تعاني منها وكذلك مدي صلاحيتها للإستخدامات المختلفة. ولهذا تم صياغة أهداف هذا البحث والتي تتمثل في دراسة لبعض أراضي محافظة سوهاج بناءً علي القدرة الخصوبية للتربة (FCC)وتحديد أهم المعوقات التي قد تواجة المستثمرين الزراعيين . تم إستخدام بيانات القمر الصناعي Landsat وكذلك نموذج الإرتفاعات الرقمية DEM والذي تم إنتاجة من بيانات القمر الصناعي SRTM . بعد دراسة هذه البيانات عن طريق التحليل المرئي لصور القمر الصناعي تم تحديد أماكن أخذ قطاعات التربة والتي تم دراستها حقلياً ومعملياً بإستخدام الطرق القياسية . وبناءً علي النتائج , تم التعرف علي 4 وحدات وهي اراضي الترسيبات النهرية Nile Alluvium (NA) والمصاطب النهرية الحديثة المرتفعة High recent river terraces (HR) و والمصاطب النهرية الحديثة المنخفضة Low recent river terraces (LR) و قاع الوديان Wadi bottom (WB) وتشير نتائج دراسة التربة وتصنيفها بناءً علي Fertility Capability Classification إلي وجود بعض المحددات الإنتاجية لهذه الأراضي. وقد صنفت أراضي NA و LR كأراضي جيدة بينما صنفت أراضي HR و WB كأراضي فقيرة وفقيرة جدا نظرا لاحتوائها علي كثير من المحددات مثل القوام , إنخفاض السعة التبادلية الكاتيونية, إنخفاض البوتاسيوم المسير, محتوي كربونات الكالسيوم المرتفع, الملوحة, والمحتوي المنخفض من المادة العضوية. ويمكن التغلب علي هذه المحددات عن طريق إستخدام الوسائل التكنولوجية والإهتمام بالعمليات الزراعية.