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SPATIAL MAPPING OF SOIL QUALITY INDICATORS FOR SOME ALLUVIAL DEPOSITS, EGYPT.

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ABSTRACT

The present study aimed at building-up a geodatabase to characterize and map the soil and terrain attributes for some alluvial deposits in Damanhour district, Egypt. This is carried out through comparing two statistical methods, namely, descriptive statistical analysis and least squares to select the optimum soil quality indicators for the study area. Moreover, geostatistical analysis was carried out to map the spatial distribution of the soil quality indicators. Finally, land capability was calculated for each soil mapping unit. GIS terrain analysis showed that the eastern part of the study area has the lowest elevation having 50% of the total area. Slope ranged from 0 to 0.50% and the main slope class was from 0 to 0.05%, which covered about 90% of the total area. The north facing directions (N, NE, NW) are the dominant aspect classes representing 35.26% of the total area, followed by the south facing directions (S, SE, SW) with 28.36 % of the total area. To categorize soil properties, 40 soil profiles were dug to 200 cm depth. Laboratory analysis indicted that the soil is characterized by clayey texture and low salinity. The most significant soil quality indicators were soil salinity, sodium adsorption ratio (SAR) and available potassium with weights 12.78%, 75.75%, and 98.16% respectively. The soil units obtained by overlay of the soil quality indicators showed that there are five soil units, namely, low saline moderately deep clayey, low saline deep clayey, saline moderately deep clayey, saline deep clayey, and highly saline moderately deep clayey having 48.10%, 14.19%, 32.62%, 4.65%, and 0.44% of the total area respectively. Land capability evaluation indicated that

there were two classes (C2 and C3) with soil salinity and hydraulic conductivity as soil limitations.

Keywords: land capability, soil quality, geostatistical analysis, GIS, soil units, kriging analysis.

INTRODUCTION

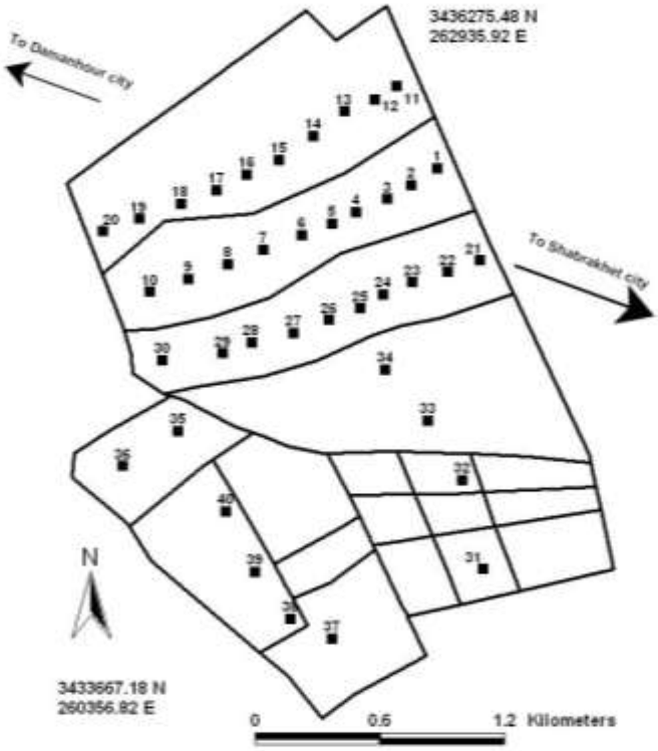
Soil is a dynamic, living, natural body and a key factor in the sustainability of terrestrial ecosystems. The components of soil include inorganic mineral material (sand, silt and clay particles), organic matter, water, gases and living organisms (Fageria, 2002). The more effective soil properties i.e. soil quality may have significant influence on the health and productivity of an ecosystem and the related environment (Larson and Pierce, 1991). Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Soil Science Society of America, 1995). This definition imply that soil quality has two parts: an intrinsic part covering soil's inherent capacity for crop growth and a dynamic part influenced by the soil user or manager. Generally, dynamic soil quality changes in response to soil use and management (Larson and Pierce, 1994). Soil quality evaluation is a tool to assess management-induced changes in the soil and to environmentally sound land management practices. Soil variability can be helpful in minimizing crop risk failure through design and implementation of site-specific management (Shukla *et al.*, 2004). Fayed (2003) found that twelve soil indicators characterized the soils of El-Bostan region, Egypt. Yehia (2004) extracted four soil quality indicators for Wadi El-Natrun district, Egypt. Western et al. (1998) examined soil moisture patterns through indicator semivariograms and showed good spatial structure for high soil moisture conditions. Water table depth has been estimated through various forms of kriging and cokriging (Desbarats et al., 2002).

The main goal of this study to use new approach for selecting the more effective soil quality indicators for the soil of the study area such as descriptive statistical analysis and least square methods (Kock and

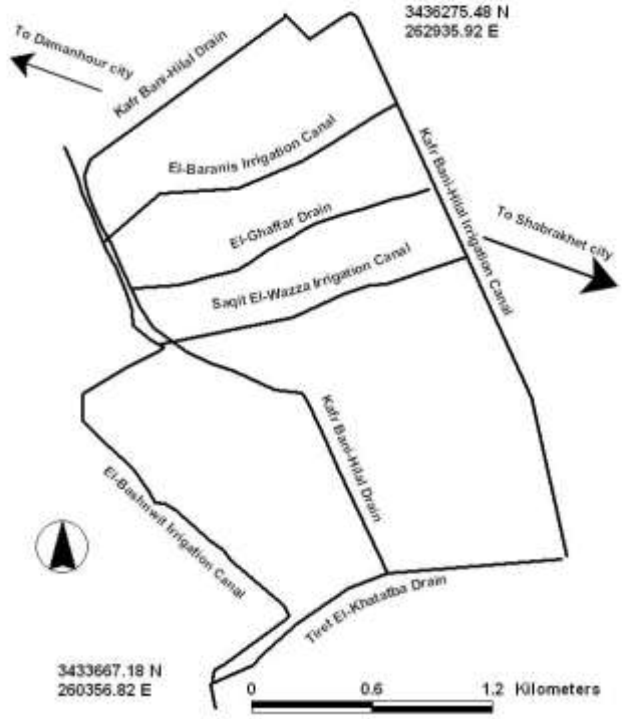
Link, 1971) and applying geostatistical analysis to identify the distribution of each soil quality indicators and overlay it in GIS environment to extract the soil mapping units.

Study Site

The study area is located at Damanhour District, El-Behira Governorate, Egypt. It covers about 1159 fed. (map 1). The soils of the study area are characterized by clayey texture, deep soil profile, and low calcium carbonate content. The main irrigation and drainage system used were surface irrigation and drainage consisted of four main irrigation canals with a total length of about 10.8 km, and three main drains with a total length of 8.9 km (map 2).



Map 1. Overlay of profile location on the study area.



Map 2. Irrigation and drainage system for the study area.

MATERIALS AND METHODS

Soil sampling: Fourty soil profiles were dug to a depth ranged from 120 to 200 cm. The soil profiles were morphologically described in the field according to FAO (1990), and geo-referenced to UTM coordinate system. The soil samples were prepared and analyzed for chemical, physical and fertility characterization according to Page et al. (1982) and Klute, (1986).

Terrain Analysis: Topographic map sheet (1:25000) of Damanhour was digitized using TerraSoft GIS software (Digital Resource System, 1991). Contour lines, spot height, irrigation canal, drainage pattern, and main roads were digitized and exported to ArcView GIS software (ESRI, 1996), and input to contour gridder module to generate Digital Elevation Model (DEM). Slope and aspect were derived using spatial analyst.

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Selection of soil quality indicators:

Descriptive statistical analysis: Statistical analysis was carried out using Excel spreadsheet. The following classical statistics parameters were calculated: minimum, maximum, mean, standard deviation and coefficient of variation (Webster 1977; and Wilding and Dress, 1983).

Least square method: A soil quality indicator is a measurable soil property that affects the capacity of a soil to perform a specified function (Karlen et aI., 1994). For evaluation of soil quality, it is desirable to select indictors that are directly related to soil quality. Because soil quality assessment is purpose and site specific, indicators used by different researchers or in different regions may not be the same.

Weights of soil quality indicators: The contribution or weighting to soil quality of each indicator is usually different, and can be indicated by a weighting coefficient. The calculation of weights assigned to each indicator is as follows (Yehia et. al., 2005):

1- The sum squared deviation from the mean was obtained for each observation

2- This amount was summed up for all observations for a specific indictor

3- Obtaining the total sum squared deviation from the mean for all indictors.

4- The weight was obtained by dividing step 2 by step 3 and multiplying by 100

5- Soil indicators that had a value less than 1 were dropped from consideration.

6- The sum of all weights was normalized to 100%.

Subdivision of indicators and their indication: Each of the indicators was divided into four classes (I, II, III, IV). Class I is the most suitable for plant growth, class II suitable to plant growth but with slight limitations, class III with more serious limitation than class II, and class IV with severe limitations for plant growth. The range for each class, which was based on previous studies on soil quality and land evaluation as shown by FAO (1976) and Sys et al., (1993) is shown in Table (1). Marks of 4, 3, 2 and 1 were given to class I, II, III and IV respectively.

Quantitative evaluation of changes in soil quality: By introducing the concept of relative soil quality index (RSQI), and with the assistance of a geographical information system (GIS), the indicators were combined into an RSQI, (Wang and Gong, 1998). According to the RSQI values, soils in the study area were classified into 5 classes from best to worst, represented as shown in table (1) by I, II, III, IV and V, respectively.

Table(1): RSQI classes and their values.

Class	RSQI value
I	90 – 100
II	80 - 90
III	70 - 80
IV	60 - 70
V	< 60

Land Evaluation: Agricultural Land Evaluation System for arid region (ALES-Arid) is a new approach for land capability and suitability evaluation (Abdel Kawy, 2004). According to (Storie, 1964); six productivity classes were identified as shown in table (2). The calculation of capability index by ALES-Arid is an indication of land capability according to multiplication method.

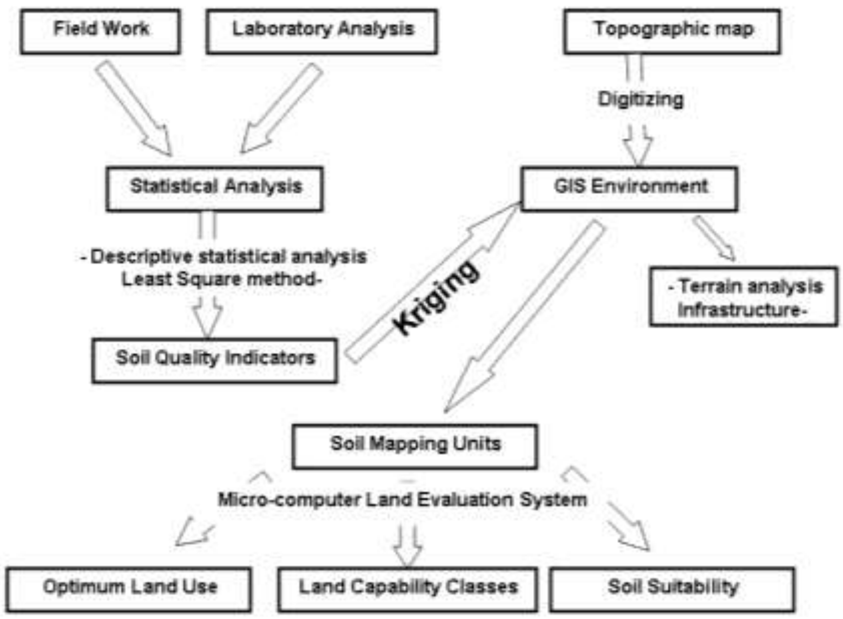
Table(2): Productivity classes and ratings according to Storie, 1964.

Class	Description	Rating (%)
C1	Excellent	80 – 100
C2	Good	60 – 80
C3	Fair	40 – 60
C4	Poor	20 – 40
C5	Very poor	10 – 20
C6	Non-agriculture	< 10

Geostatistical analysis

The Semi-Variogram: The semi-variogram is the most important tool in geostatistical applications to soil. It represents the average rate of change of property with distance. It is the basis for modeling the data set and for drawing a contour maps or isarithms, (Burgess& Webster 1980). The obtained semi-variogram values for each lag were fitted to one of the semi-variogram function using the GSPLUS software Ver. 5.3.1, Gamma Design (2001).

Kriging analysis: Kriging is a method of interpolation using the weighted local averaging. It is optimal in a sense that the weights are chosen to give unbasied estimates, while keeping the estimation variance at minimum (Webster, 1977). Figure (1) summarizes the



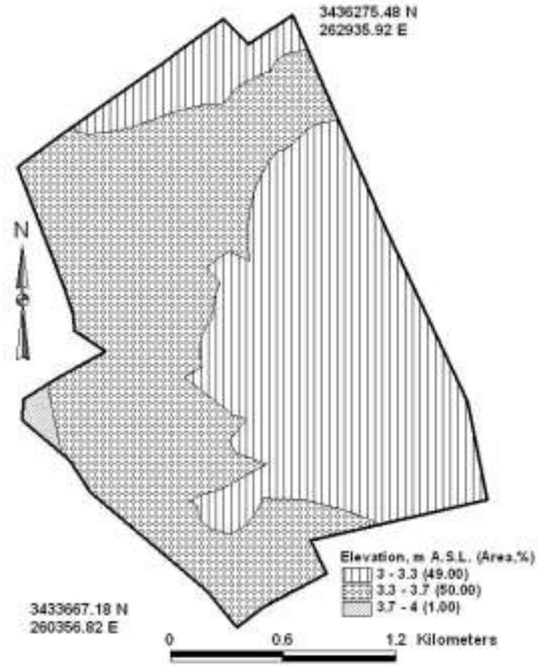
approach employed in this study

Figure (1): Flow chart representing methodology of study

RESULTS AND DISCUSSION

Terrain analysis: The Digital Elevation Model (DEM) indicated that the elevations varied from 3 to 4 m A.S.L. The eastern part of the study area has the lowest elevation. The dominant elevation ranged from 3.3 to 3.7 m A.S.L. composed total area as shown in map 3. It is noticeable that the north facing directions (N, NE, NW) is the dominant aspect representing 35.26 % of the total area, followed by the south facing directions (S, SE, SW) with 28.36 % of the total area.

Statistical soil parameters: Table (3) shows the descriptive statistical analysis which indicated that the clay content ranged from 38.75 to 58.00 %, soil salinity varied from 1.58 to 5.12 dS/m and with low calcium carbonate content (1.35 to 3.85%). SAR shows highest variance followed by Available K followed by soil salinity, so that the soil quality indicators for the study area were the parameters have the highest variance. Table (4) indicated the three soil quality indicators extracted from the least squire methods.



Map 3. Digital Elevation Model and area percentage of study area.

Table (3): Statistical characterization of soil properties

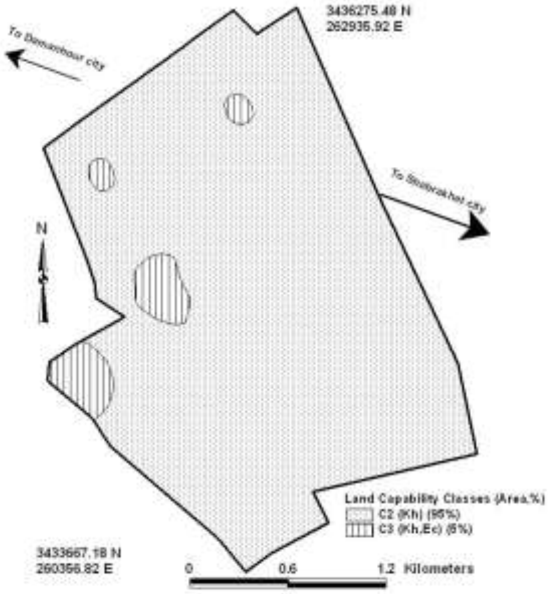
Soil Property	Statistical parameters					
	Min	Max	Mean	Variance	St. Dev.	C.V.
Ec, dS/m	1.58	5.12	2.69	0.62	0.79	**29.27**
SAR	2.74	11.52	5.56	3.68	1.92	**34.53**
pH	7.16	8.32	7.56	0.09	0.31	4.16
$CaCO_3$, %	1.35	3.85	2.61	0.46	0.68	26.98
Av. K, ppm	374	736.25	466.74	6333	150.62	**32.27**
Av. P, ppm	0.065	3.90	0.57	0.37	.025	4.39
Av. N, ppm	37.25	77.25	54.69	118.64	10.89	19.92
Clay, %	38.75	58.00	46.94	20.96	4.58	9.75
Silt, %	16.87	34.50	28.73	12.33	3.51	12.22
Sand, %	19.25	41.87	24.32	17.13	4.14	17.01

Table (4): Soil quality indicators, their weights and classes results.

Indicator	Weight	I	II	III	IV
EC, dS/m	12.78	< 2	2 – 4	4 – 8	> 8
SAR	75.75	< 15			> 15
Available K, ppm	98.16	> 270	135 - 270	70 - 135	< 70

Land capability: The ALES-Arid model provides prediction for general land use capability for a broad series of possible uses. According to the model prediction, most of the study area was classified as C2 t, which indicated fair capability with soil texture as limiting factors. Map (4) illustrates the distribution and percentage of each land capability class in the study area.

Semi-Variogram of the soil properties: Semi-variograms of individual soil properties were fitted to four models. Soil salinity, sodium adsorption ratio (SAR), and depth were fitted to the Spherical model; clay content was fitted to the Exponential model and available potassium fitted to the Gaussian model as shown in figure (2). The parameters of these models for different soil properties are shown in table (5). It's clear that available potassium has the highest nugget variance followed by depth; which indicates their strong spatial dependence and high inherited variability, (Warrick et al., 1986). Maps (5 and 6) show the distribution of some soil properties in the study area.



Map (4): Land capability classes for the study area.

Table (5): Semivariogram types and parameters of soil quality indicators.

Soil quality indicator	Model	Nugget (C_o)	Sill (C1)	Range (a)	r^2	Lag (m)
EC, dS/m	Spherical	0.001	0.717	181	0.734	2500
SAR	Spherical	0.01	3.61	318	0.708	3500
Clay %	Exponential	13.26	26.53	600	0.965	1000
Available K, ppm	Gaussian	340.00	6402.0	257	0.653	1500
Depth, cm	Spherical	130.00	766.10	287	0.942	2000

Soil mapping units: The kriged maps of soil properties were overlain in GIS environment to produce the soil mapping units. Five soil units were dominated prevailed, namely, low saline moderately deep clayey soil (48.10%), low saline deep clayey soil (14.19%), saline moderately deep clayey soil (32.62%), saline deep clayey soil (4.65%) and highly saline moderately deep clayey soil (0.44%) as shown in map 4. The soil is characterized as clayey deep and moderately deep soil as shown in map 7.

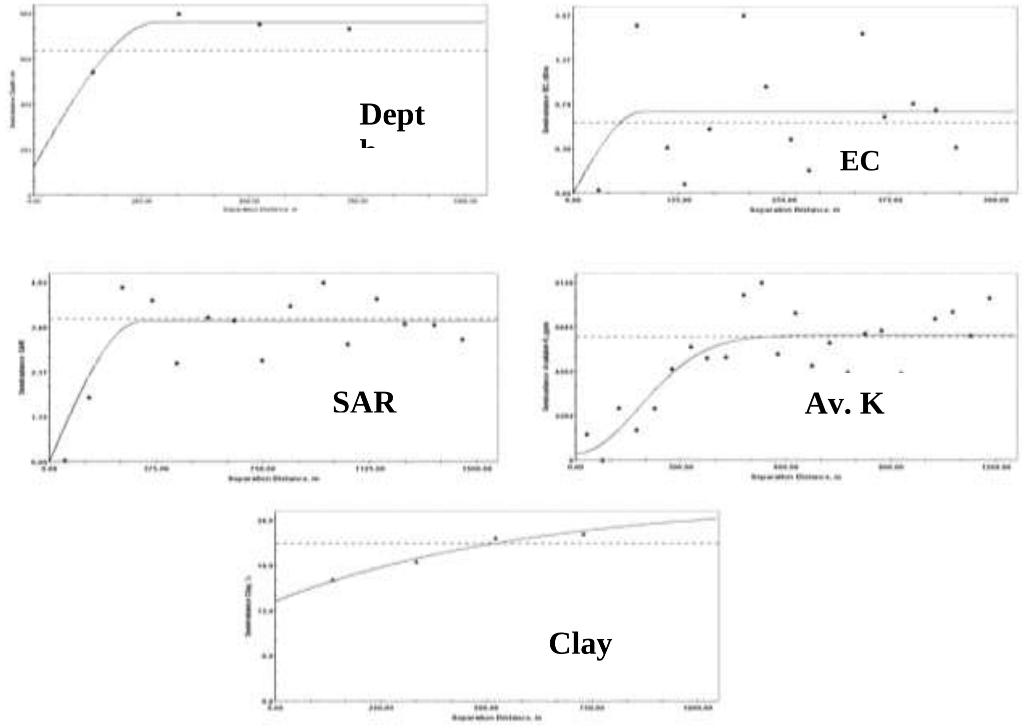
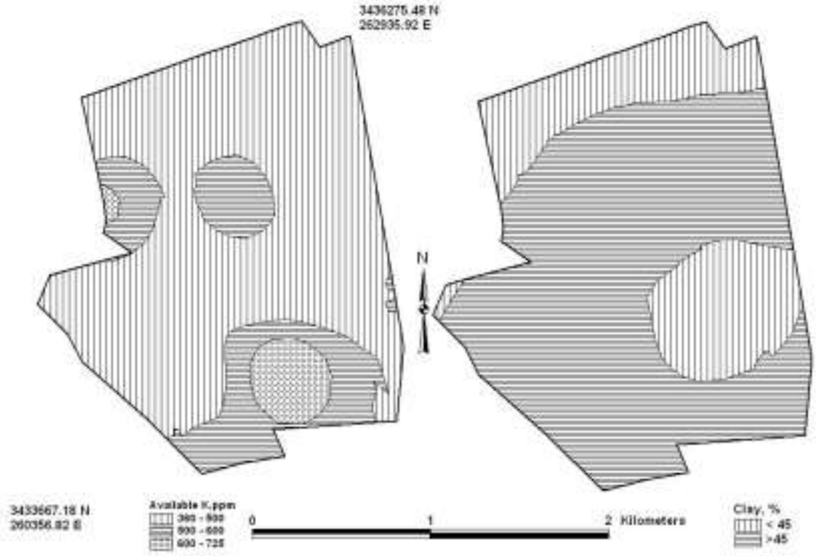
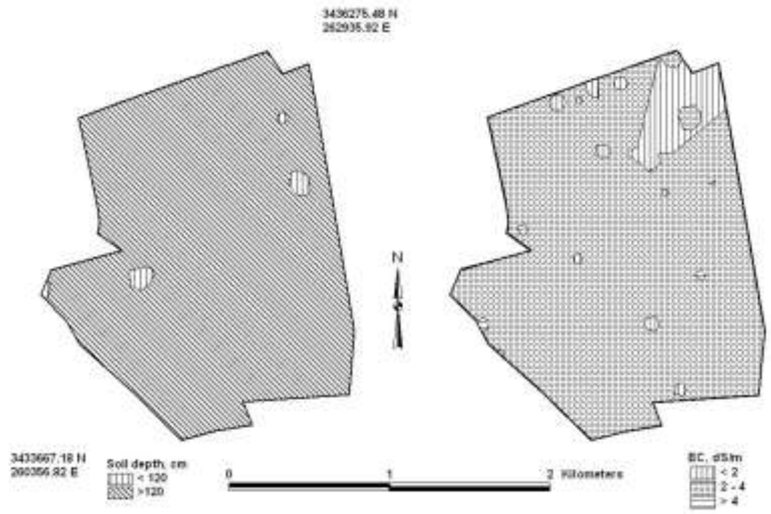


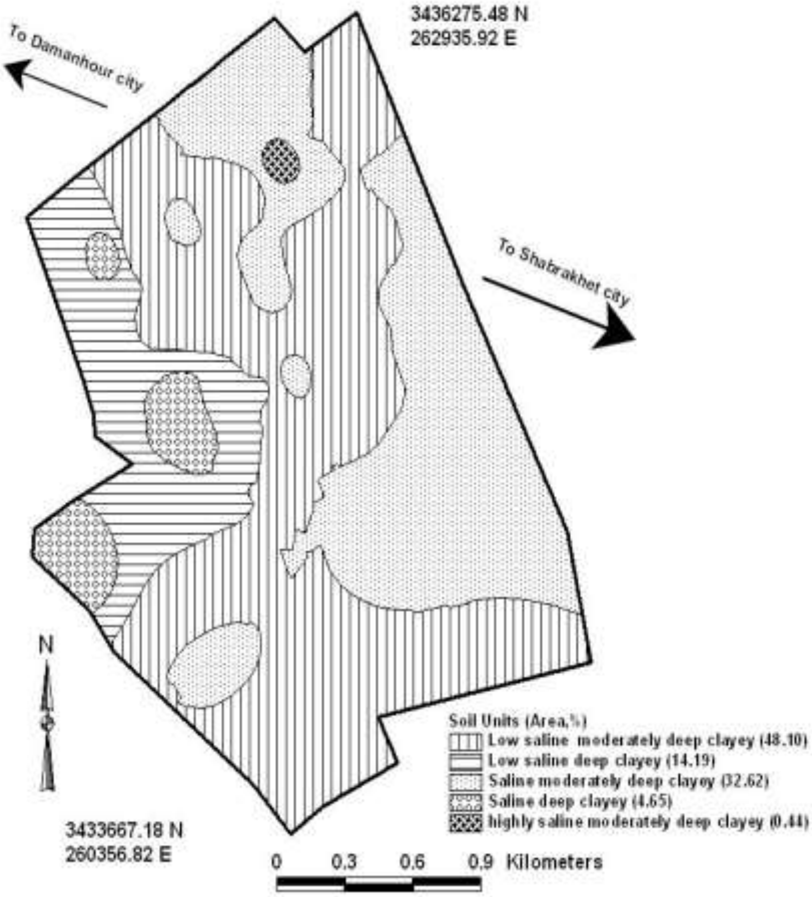
Figure (2): The semivariograms of soil properties.



Map (5): Distribution of clay content and available K using kriging analysis.



Map (6): Distribution of soil salinity and soil profile depth using kriging analysis.



Map 7. Soil mapping units of the study area.

CONCLUSION

The comparison between classical descriptive statistical method and least square method to select the optimum soil quality indicators indicated the need for more studies on different soil properties and more soil samples to select the best method. Due to the homogeneity of the soil properties of the study area, kriging maps don't show variation, and the heavy clay texture of the study area shows that the main limitations in land capability were soil salinity and hydraulic conductivity. So more amendment of organic matter and water leaching requirements were needed and must be taking into consideration for proper management of the heavy textured soils.

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الملخص العربى

الخرائط الفراغيه لدلائل جودة التربة لبعض الرسوبيات النهريه - مصر

رجب اسماعيل فايد وهيثم عبد اللطيف يحيى وايهاب محرم مرسى
معمل بحوث الاراضى الملحية والقلوية – معهد بحوث الاراضى والمياه والبيئة – مركز البحوث الزراعية- الجيزة

تهدف هذه الدراسة الى بناء قاعدة معلومات رقمية للتعرف على البنية الاساسية لبعض الرسوبيات النهريه بمركز دمنهور – محافظة البحيرة وذلك للتعرف على خواص التربة وكذلك تحديد الوحدات الارضية المختلفة الممثلة للمنطقة وقد تم ذلك من خلال مقارنة طريقتان احصائيتان مختلفتان لاختيار افضل دلائل لجودة التربة والتى تصف منطقة الدراسة ثم استخدام التحليل الجيواحصائى لدراسة توزيع تلك الخواص فى منطقة الدراسة التى تمثل حوالى 1100 فدان وفى النهاية يتم عمل تقويم لقدرة الوحدات الارضية وتحديد معوقات الاستغلال الزراعى. تم بناء قاعدة البيانات فى بيئة نظم المعلومات الجغرافية التى اوضحت ان ارتفاع منطقة الدراسة يتراوح من 3 الى 4 متر فوق مستوى سطح البحر وان الجزء الشرقى من منطقة الدراسة اكثر انخفاضا من اى جزء اخر والارتفاعات السائدة من 3.3 الى 3.7 متر وتغطى مساحة حوالى 50% من اجمالى المساحة المدروسة اما بالنسبة للميل فيتراوح من صفر الى 0.50% واتجاهات الميل السائدة فى اتجاه الشمال يليها اتجاه الجنوب وتغطى مساحة 35.26% و28.36% على التوالى ولتحديد خواص التربة تم عمل 40 قطاع ارضى تتراوح اعماقها من 120 الى 200 سم ومن خلال الدراسة الحقلية والتحليلات المعملية تم تحديد ان اراضى المنطقة تتميز بقوامها الثقيل وملوحة التربة المنخفضة ومن خلال استخدام برامج الحاسب الالى لتقويم التربة للاستغلال الزراعى وجد ان هناك قسمان اساسيان وهما C2 & C3 وان المعوقات الاساسية هى ملوحة التربة ومعامل التوصيل الهيدروليكى وهذا يرجع الى قوام التربة الثقيل وقد وجد ان دلائل جودة التربة الممثلة لمنطقة الدراسة هى ملوحة التربة ونسبة الصوديوم المدمص والبوتاسيوم المتاح ولها اوزان كالتالى 12.78% و75.75% و98.16% على التوالى وقد اوضحت نتائج التحليل الاحصائى ان ملوحة التربة وعمق القطاع الارضى ونسبة الصوديوم المدمص تتبع فى توزيعها Spherical model اما بالنسبة للبوتاسيوم المتبادل فتتبع فى توزيعها Gaussian model اما بالنسبة لنسبة حبيبات الطين فتتبع Exponential model. ومن خلال عمل التحليل الجيواحصائى لهذه الخواص المختلفة ومطابقتها من خلال نظم المعلومات الجغرافية تم الحصول على خمس وحدات ارضية ممثلة لمنطقة الدراسه.