Spatial Distribution and Mapping of Some Calcareous Soil Properties Affected by Salts in West Nubaria Area, Egypt

Using Geostatistical Analysis And GIS Techniques

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ABSTRACT: Geostatistics provide descriptive tools to describe the spatial distribution of soil properties was presented according to its semivarioms.This study aimed to investigate variability of some soil properties in West Nubaria area of Egypt**.** It covers parts of Alexandria and El-Behira Governorates with total area about 5000 fed. The results revealed that studied soils are characterized by sandy loam to loam sandy texture in most samples. However, total soluble salts, as expressed by the electrical conductivity and sodium adsorption ratio indicate that most of the studied soils are characterized by their moderate to high EC and SAR values. The EC values ranged between 0.78 and 9.69 dS/m, SAR values being in the range from 1.03 to10.31 dSm^{-1}, total calcium carbonate content ranged between 12.12 and 64.68%. Organic matter ranged between 0.18 and 1.36%. pH values ranged between 7.50 and 8.40. The amounts of sand, silt and clay varied from 66.36 to 85.36, 5.00 to 18.00 and 9.64 to 20.24%, respectively. Results of soil spatial variability analysis for some soil characteristics show that variation of soil salinity, available nitrogen and available potassium followed Gaussian model at surface soil layers , but it follows the Exponential model for the topsoil layers for both total calcium carbonate and available phosphorous. These models were used to plot the spatial distribution maps and the three-dimension graphs of the previous soil properties, and consequently to create the soil mapping through GIS techniques.

Keywords: Calcareou soils, Salinity, Geostatistical analysis, Isotropic semivariogram, Geographic Information Systems (GIS).

INTRODUCTION

The Egyptian governments have adopted strategies whose main objective is to narrow the food gap resulting from land degradation and the population increase, which estimated at 99.6 million in 2019 **(CAPMAS 2019).**

The importance of the agriculture sector to the Egyptian economy along with the ever-increasing population emphasize the need for desert land reclamation as a vital key to narrow the food gap resulting from land degradation and the population growth **(Abd El-Kawy *et al.*, 2019)**. Salinity intrusion is one of the major environmental issues throughout the world **(Khanam *et al.*, 2020)**.

Calcareous soils dominated in arid and semi-arid regions as a result of little leaching. Although it may found in semi-humid and humid regions were the soil derived from parent material rich in $CaCO_3$ as limestone **(Taalab *et al.*, 2019).** The soil in arid and semi- arid region are followed to calcisols according to American soil classification system with a huge secondary deposition of calcium carbonate resulting from precipitation from soil solution caused by evaporation in arid conditions **(FAO 2016).**

Spatial variability analysis of meteorological elements and precise identification of possible causes of thermal stress in poultry housing help producers in the decision making process **(Lopes *et al.*, 2020)**.

Ecological risk assessment and source identification of heavy metal pollution in vegetable bases of Urumqi, China, using the positive matrix factorization (PMF) method. Heavy metal pollution is a widespread problem and strongly affects human health through the food chain **(Kuerban *et al.*, 2020)**.

Information on spatial analyses in land uses is important for site-specific nutrient management **(Hussain *et al.*, 2021)**.

Natural soil-forming factors such as landforms, parent materials or biota lead to high variability in soil properties. However, there is not enough research quantifying which environmental factor (s) can be the most relevant to predicting soil properties at the catchment scale in semi-arid areas **Zeraatpisheh *et al.* (2019)**. Soil surveying and mapping is an important operation in soil science, and characterization of their properties is a key step in understanding soil quality **Oumenskou *et al.* (2019)**.

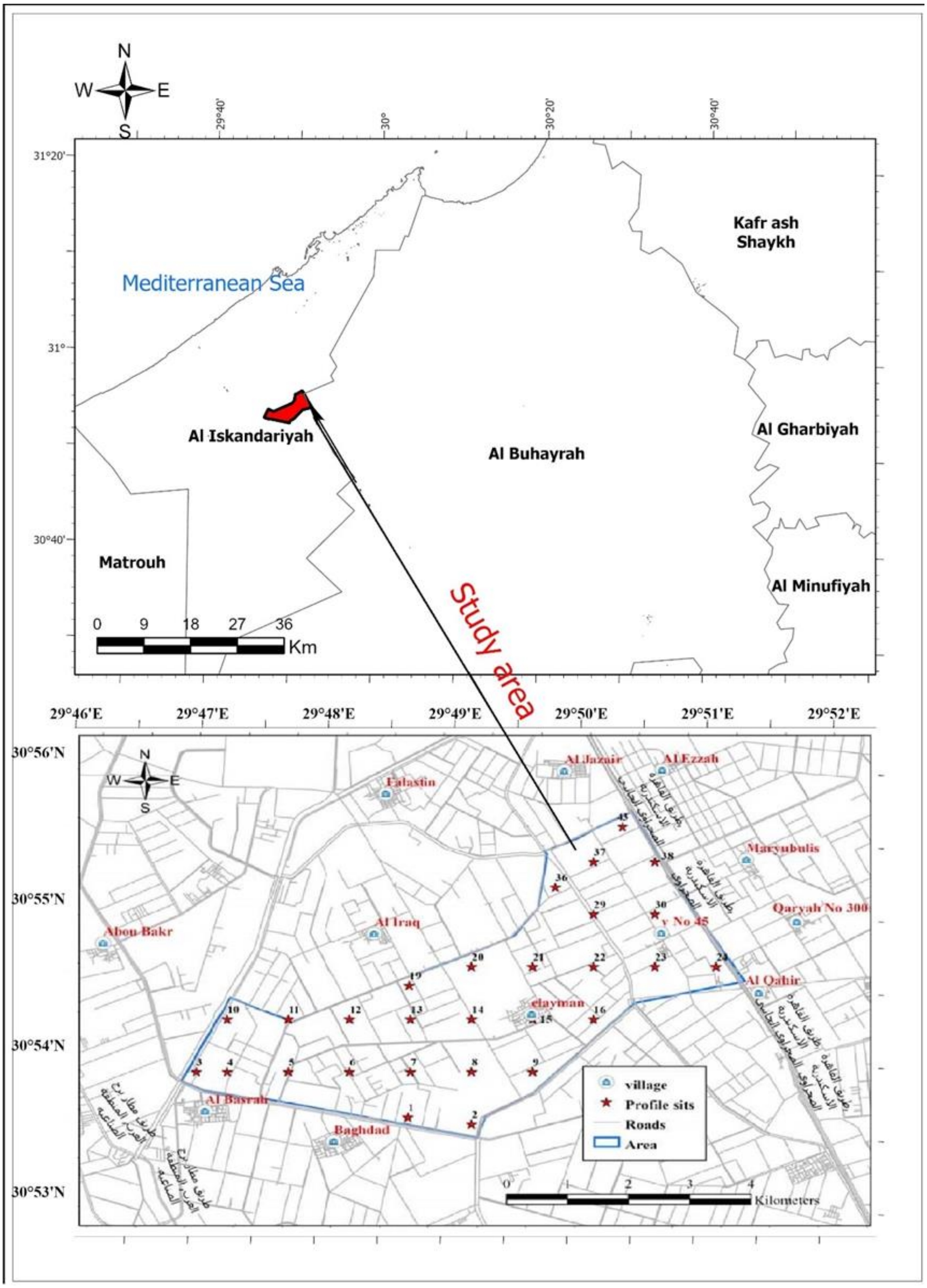
As an important GIS function, spatial interpolation is one of the most often used geographic techniques for spatial query, spatial data visualization, and spatial decision-making processes in GIS and environmental science. However, less attention has been paid on the comparisons of available spatial interpolation methods, although a number of GIS models including inverse distance weighting, spline, radial basis functions, and the typical geostatistical models (i.e. ordinary kriging, universal kriging, and cokriging) are already incorporated in GIS software packages **(Meng *et al.*, 2013)**.

The objective of this work was to study the spatial distribution of some calcareous soils properties affected by salts in West Nubaria area, Egypt

MATERIALS AND METHODS

The study area:

The studied area is located between 30.53 to 30.56 N and 29.52 to 29.46 'E at Mariout area, west of Nubaria**.** It covers parts of Alexandria and El-Behira Governorates with total area about 5000 fed. 28 soil samples representing the studied area were taken were geo-located using GPS as shown in Map (1). Moreover, these observations were used to carry out the physical, chemical and fertility characterization of the land use classes.



Map (1) The location of the study area and soil observations

Laboratory analysis:

The soil samples were air dried, passed through a 2mm sieve, and then stored for analysis. The following determinations were carried out:

- Soil physical characters

Soil physical characters were determined according to **Page *et al.* (1982)**, which included soil texture, Saturation Percentage (S.P%), Available water (AW), Bulk densities and Moisture Content (θv %).

- Soil chemical characters:

The chemical determinations were made according to the procedures outlined in the methods of soil analysis **(Page, 1982).**

Soil pH, Electrical Conductivity (dS/m), soluble cations (meq/l), soluble anions (meq/l), total calcium carbonate percent (%) which were determined by calcimeter., and organic matter (%) were determined according to the methods outlined in **Carter and Gregorich (2008).**

- **pH** meter Model No. (446/1) was used in measuring the soil pH in a soil paste and in a soil water ratio of 1:2.5.
- **Electrical conductivity** of the saturation extract (EC), It was measured by an EC meter Model No. (CCS51).
- **Soluble cations and anions:-**

Ethylcne diamine tetraacetate (EDTA) was used for the determination of calcium plus magnesium. Sodium and potassium were measured using flame photometer.

- **Calcium and magnesium:** determined in soil-water extract (1:1) by titration with versenate (EDTA) solution using Muroxide as indicator for calcium and Erichrome black T (E.B.T) for calcium plus magnesium, according to **(Jackson 1973)**.
- **Sodium and potassium:** soluble sodium and potassium in soil: water 1:1 w/v extract were determined using flame photometry method according to **(Jackson 1973)**.
- **Carbonate and bicarbonate:** soluble Carbonate and bicarbonate were determined volumetrically in soil: water 1:1 w/v extract by titration against (0.05N) hydrochloric acid solution using methyl orange as an indicator according to **(Jackson 1973)**.
- **Chlorides:** soluble chloride was determined volumetrically in soil: water 1:1 w/v extract by titration against (0.05N) silver nitrate solution with potassium chromate as indicator according to **(Jackson 1973)**.
- **Sulphate:** soluble sulphate in soil: water 1:1 w/v extract by were determined using spectrophotometer according to **(Jackson 1973)**.
- Sodium Adsorption Ratio (SAR) was calculated by the following formula **(Richards, 1954):**

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

- **Calcium carbonate.**

It was determined gravimetrically by carbon dioxide loss and volumetrica1ly by calcimeter method.

Soil fertility characters:

- **Organic matter**

Walkley and Black (wet oxidation) method was used in the determination of organic carbon. To obtain the organic matter a factor of 1.72 was used.

- Soil available nutrients:

Soil available macro-nutrients (N, P and K) as follows:

- **Available nitrogen content (mg/kg):**

The soil sample was extracted by 2M KCl (1:20), available N was determined in soil extract by Nessler's method **(Bermner and Mulvaney, 1982).**

- **Available phosphorus content (mg/kg):**

Available phosphorus was extracted with 0.5 M $NaHCO_3$ solution adjusted to pH 8.5 according to **Olsen *et al.* (1954).** Available phosphorus was determined by ascorbic acid molybdenum blue method. Reading was recorded on spectrometer using wavelength of 880 nm **(Jackson, 1973).**

- **Available potassium content (mg/kg):**

The extraction was done by ammonium acetate (1N of pH 7.0) and potassium was determined by flame photometry according to **(Jackson, 1973)**

Descriptive statistical parameters:

Minimum, maximum, mean, standard deviation and coefficient of variance were calculated using IBM SPSS software Ver. 19 (2010).

Building up Digital Georeference Database:

Data input process is the operation of entering the spatial and non-spatial data into GIS using ArcGIS software (ESRI, 2012). Each soil observation was geo-referenced using the Global Positiong Systems (GPS) and digitized. The different soil attributes were coded, and new fields were added to the profile database file in ArcGIS software.

Generation of DEM

DEM is defined as any digital representation of the continuous variation of relief over space (Burrough, 1986 by means of digitized contour lines of 1:50000 scaled topographic maps in every 10 m interval as well as spot heights, DEM of the study area was performed by using interpolation procedure. Contour Gridder extension was used to generate the Digital Elevation Model (DEM) within ArcGIS 10.1 (ESRI,2012). DEM was analyzed to generate the degree of slope classes and Aspect.

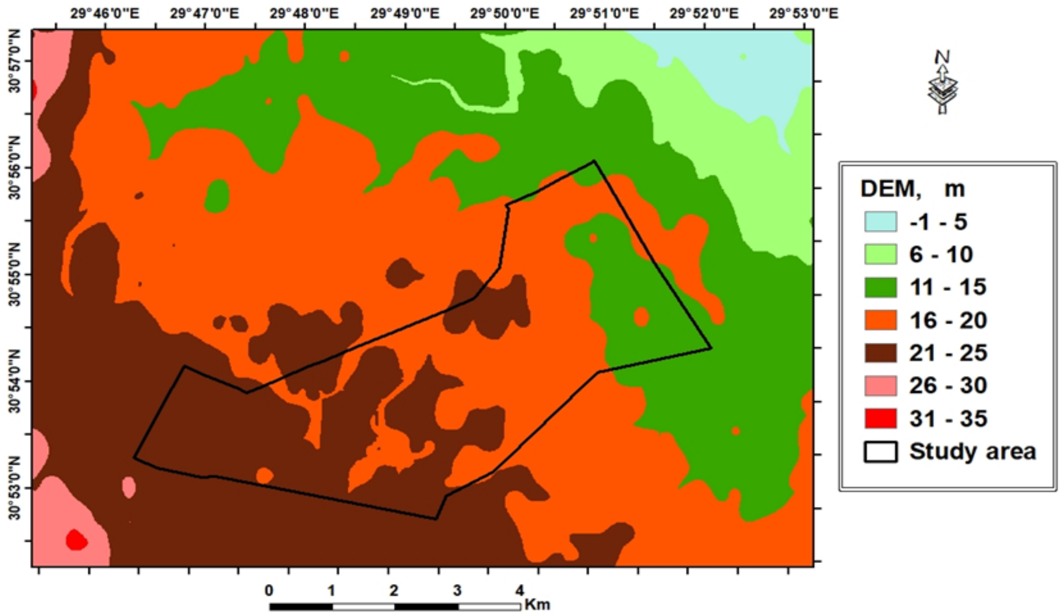
Geostatistical analysis:

The semi-variogram's parameters for the soil properties that have high range of variation were calculated using the GSPLUS (GS+) geostatistical analysis software, Gamma Design (1991). The model with best fitting which corresponds to the high correlation was selected to express the spatial variability of each tested soil property. The semi-variogram equations were created according to the fitted models.

RESULTS AND DISCUSSION

Land surface analyses:

Digital elevation model (DEM) of the studied area contributes to the storage of elevation data as digital map and 3-D, (Map 2). The most advantage of the GIS is the ability to process elevation data in a digital format, and obtains valuable information about the land surface; Carter (1988). DEM was obtained from the digital contour map, using the interpolation technique. The methods to detect and quantify them are reviewed and discussed. Different product levels are considered, i.e., from point cloud to grid surface model and to derived topographic features, as well as the case of global DEMs. Finally, the issue of DEM quality is considered from the producer and user perspectives **(Polidori and El Hage 2020).**



Map (2): the Digital Elevation Model (DEM) of the study area

Characterization of the surface studied soils

The minimum, maximum and average values of main physical and chemical properties of surface soil are shown in **(Table 1).** The data show that the studied soils are characterized by sandy loam to loam sandy texture in most samples. Data of total soluble salts, as expressed by the electrical conductivity and sodium adsorption ratio indicate that most of the studied soils are characterized by their moderate to high EC and SAR values. The EC values ranged between 0.78 and 9.69 dS/m, SAR values being in the range from 1.03 to10.31 dSm^{-1}, total calcium carbonate content ranged between 12.12 and 64.68%. Organic matter ranged between 0.18 and 1.36%. pH values ranged between 7.50 and 8.40. The amounts of sand, silt and clay varied from 66.36 to 85.36, 5.00 to 18.00 and 9.64 to 20.24%, respectively. Saturation ratio ranged between 38.7 and 41.30%, available water ranged between 9.17 and 85.00 mm/m, bulk densities range from 1.55 to1.62 gm/cm^3, moisture content range from 11.1 to17.40%. For cations, calcium values ranged between 1.20 and 16.20, magnesium values ranged between 0.01 and 10.20, sodium values ranged between 3.48 and 35.67 and potassium values ranged between 0.20 and 20.80. For anions, bicarbonate values ranged between 2.50 and 5.63, chloride values ranged between 1.43 and 19.99 and sulphate values ranged between 0.28 and 29.98. Available macronutrients (NPK), nitrogen values ranged between 1.73 and 18.87, phosphorus values ranged between 5.50 and 160.50 and potassium values ranged between 200.00 and 3200.00. Distribution of soil salinity (EC), calcium carbonate ($CaCO_3$), Available (N,P,K) in the topsoil samples as shown in Maps from (3 to7) respectively.

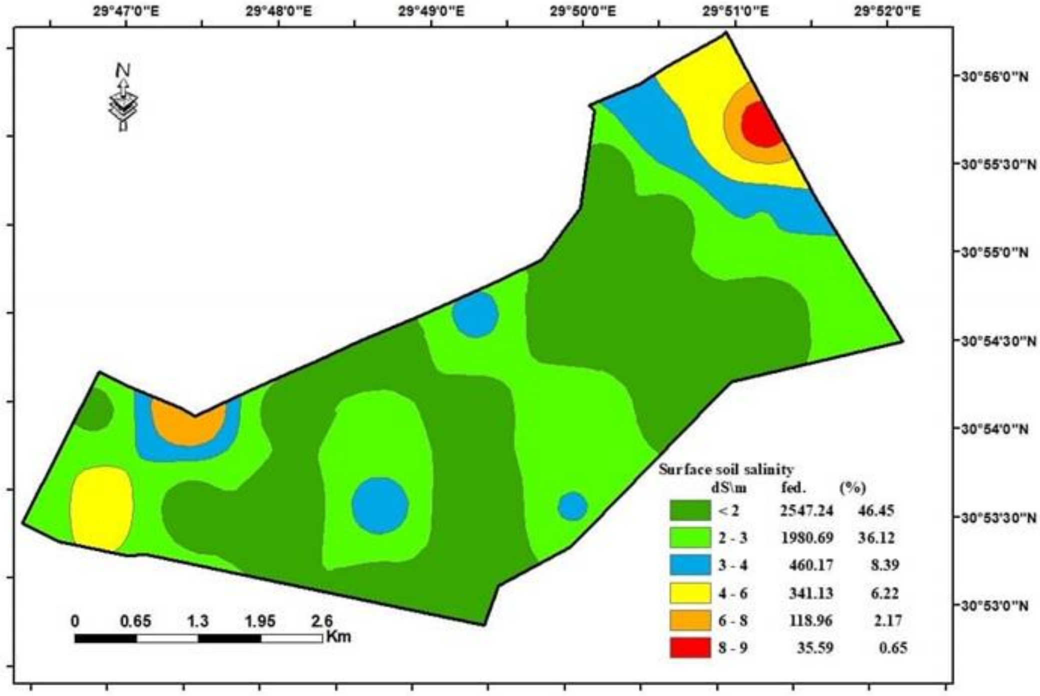
Many definitions of calcareous soils were proposed in the last years. These definitions were mainly depending on the chemical properties and the total $CaCO_3$ content regardless the active $CaCO_3$ content and the physical and hydraulic properties of these calcareous soils. **(Shawky *et al.*, 2004).** The study of phosphorus sorption of calcareous soils is an important factor for development of successful fertilizer and manure management practices **(Leytem and Westerman, 2003).** The soil characteristics influencing P sorption include: clay content, organic matter, pH, soil texture and Ca content **(Hedley and McLaughlin, 2005).** Soil properties that affect the rate of phosphate retention in 28 contrasting calcareous soils from different geographical regions (14 soils from western Azerbaijan in Iran (WAI) and 14 soils from Western Australia in Australia (WAA). The results showed that the mean apparent recoveries of applied available P (Olsen P based recover) after 160 days of incubation at field capacity was found to be 7 % for the soils of WAI and 25 % for the soil of WAA **(Samadi., 2006).** The secondary calcium carbonates are formed under arid and semiarid climatic conditions when the carbonate concentration in soil solution remains high. Accumulation starts in the fine and medium-sized pores at the surface of contact between the soil particles. This accumulation may be rather concentrated in a narrow zone of the solum or more dispersed, depending upon the quantity and frequency of rainfall, topography, soil texture, and vegetation **(FAO, 2016)** Calcareous soils are alkaline because of the presence of $CaCO_3$, which dominates their chemistries. Depending on the solubility product of $CaCO_3$, the dissolution results in a high solution HCO_3 - concentration, that buffers the soil in the pH range of 7.5 to 8.5 **(Imas, 2000):** as $CaCO_3 + H_2O \leftrightarrow Ca^{2+} + HCO_3^- + OH^-$ .41 As salts dissolve, the cations entering solution are attracted to the exchange sites usually according to valence and mass action.

This is attributed to the high pH of soil solution and reduced nutrient availability. Improved nutrition management is required to grow crops successfully on calcareous soils. Fertilizer management on calcareous soils differs from that on non-calcareous soils because of the effect of soil pH on soil nutrient availability and chemical reactions that affect the loss or fixation of some nutrients. The presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of nitrogen, phosphorus, iron, zinc, magnesium, calcium, potassium and copper **(Marschner, 1995).**

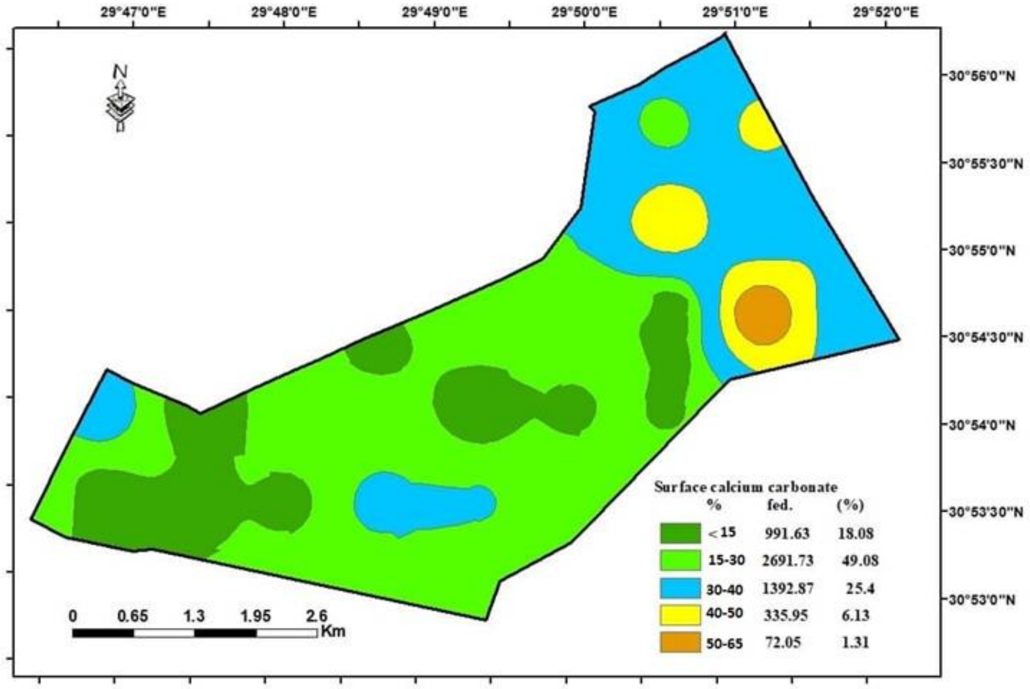
Soil particle size and mineral composition have a significant influence on the formationof phosphorus. When phosphorus is fixed by calcareous soil, an adsorption reaction on the surface of minerals occurs first, thereby forming phosphorus coordination compounds. The compounds slowly deposit on the minerals surface before being fixed by the soil, such as Al-P on the surface of kaolinite and muscovite, Ca-P on the surface of calcite and dolomite, and Fe-P on the surface of amorphous iron oxide. Because calcareous soil is alkaline, the precipitation of Al-P and Fe-P is inhibited **(Gérard 2016 and Kasama *et al.*, 2004)**, and the formation of Ca10-P with strong stability is beneficial. Therefore, carbonate minerals represent the dominant fixator of phosphorus in calcareous soil **(Carreira *et al.*, 2006)**, particularly in sand. Consequently, in calcareous soil, the form of phosphorus is affected by soil mineral species and particle size. The content of Ca-P fixed by carbonate minerals increases with particle size, whereas kaolinite, muscovite, and iron oxide are enriched in fine fractions, leading to the contents of Al-P and Fe-P decreasing with an increase in particle size.

Table (1): Statistical parameters of the estimated properties of soil samples

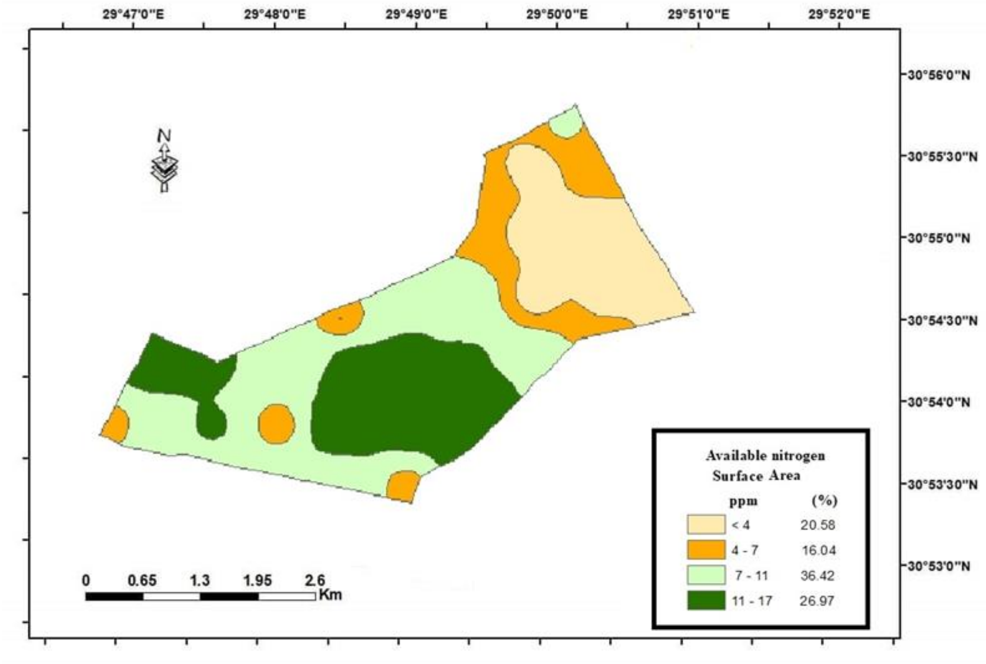
Soil properties	Mean	Max	Min	SD	Median	CV %	Var.
pH	8.00	8.40	7.50	0.19	8.00	0.02	0.04
EC (dSm^{-1})	2.55	9.69	0.78	1.89	1.80	0.74	3.56
Soluble cations ($meql^{-1}$)							
Ca^{+2} (meq/l)	6.15	16.20	1.20	4.98	4.20	0.81	25.72
Mg^{+2} (meq/l)	3.43	10.20	0.01	2.79	2.40	0.81	8.05
Na^{+} (meq/l)	9.85	35.67	3.48	5.97	8.48	0.61	36.97
K^{+} (meq/l)	1.35	20.80	0.20	3.77	0.52	2.78	14.72
Soluble ainons ($meql^{-1}$)							
HCO_3^- (meq/l)	3.91	5.63	2.50	0.85	3.75	0.22	0.74
Cl^- (meq/l)	4.69	19.99	1.43	4.28	3.57	0.91	19.03
SO_4^- (meq/l)	11.33	29.98	0.28	9.55	6.42	0.84	94.65
SAR (%)	4.93	10.31	1.03	1.75	4.73	0.35	3.16
$CaCO_3$ (%)	34.24	64.68	12.12	15.05	92.83	0.44	226.65
Sand (%)	73.67	85.36	66.36	3.86	73.56	0.05	0.15
Silt (%)	9.50	18.00	5.00	2.41	10.00	0.25	0.06
Clay (%)	16.83	20.24	9.64	2.63	16.94	0.16	0.07
S.P %	39.88	41.3	38.7	0.57	39.85	0.01	0.33
A.W(mm/m)	60.41	85.00	9.17	13.40	62.50	0.22	179.67
Bulk density (gm/cm^3)	1.59	1.63	1.55	0.02	1.59	0.01	0.01
Ө v %	13.05	17.4	11.1	1.85	12.70	0.14	3.41
OM (%)	0.66	1.36	0.18	0.31	0.73	0.47	0.09
N ($mgkg^{-1}$)	8.21	18.87	1.73	4.79	7.62	0.58	22.98
P ($mgkg^{-1}$)	48.73	160.50	5.50	32.92	41.25	0.68	1083.73
K ($mgkg^{-1}$)	717.86	3200.0	200.0	664.29	450.00	0.93	441288



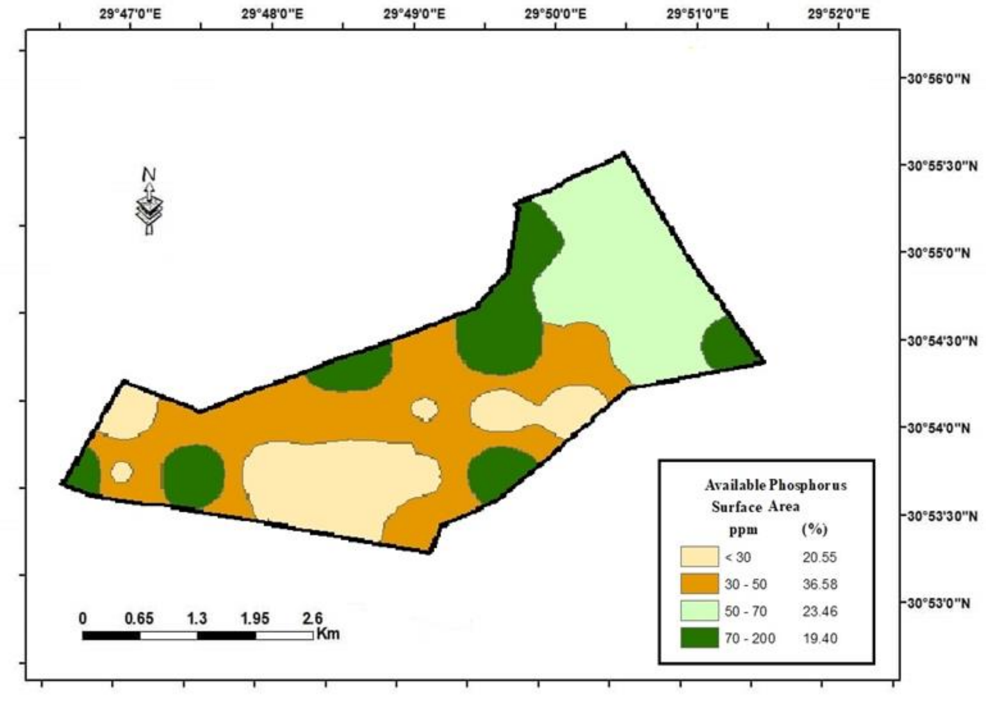
Map (3): Distribution of soil salinity (EC) in the topsoil samples



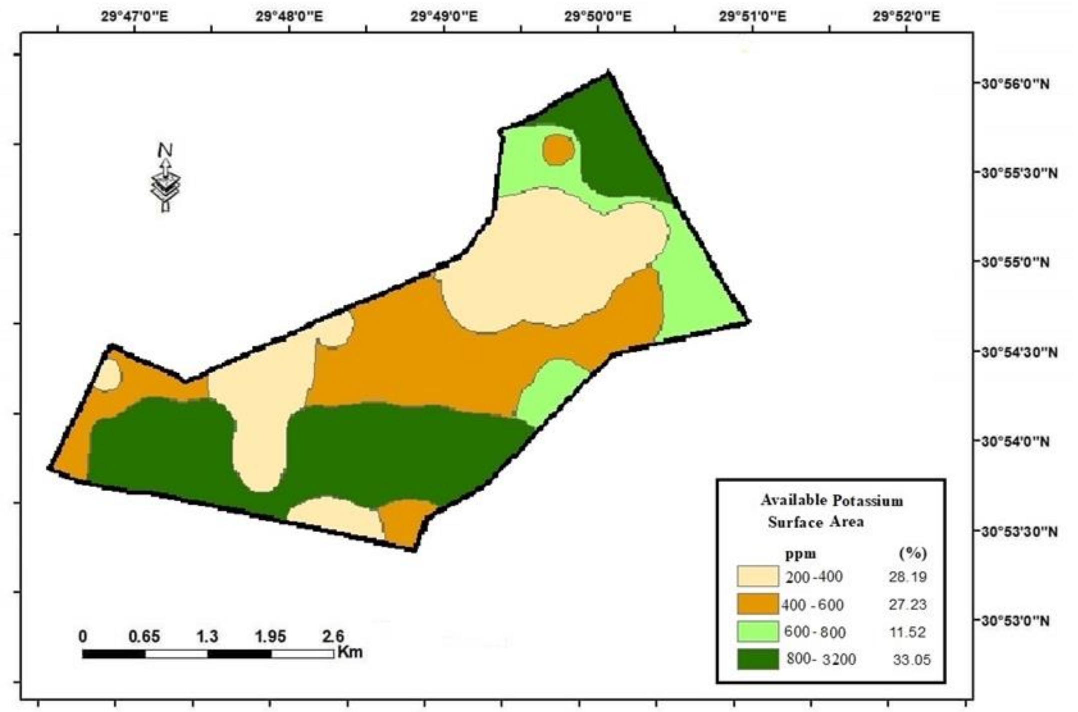
Map (4): Distribution of calcium carbonate ($CaCO_3$) in the topsoil samples



Map (5): Distribution of Available Nitrogen in topsoil sample



Map (6): Distribution of Available Phosphorus in the topsoil sample



Map (7): Distribution of Available Potassium in the topsoil sample

Geostatistical analysis

Geostatistical analyzes of soil parameters according to their semi-variables are presented. Classical statistics cannot show the spatial variance of soil properties. The spatial behavior of soil properties was evaluated using semi-variable plots with its best fit model.The quasi-isotropic profiles of soil properties are shown in Figures 1 to 5. Semi-isotropic analysis of soil parameters is depicted in the figures, spherical, exponential or linear models were fitted to half-plots and selected based on the best visual fit and the corresponding coefficient of determination (R2). In addition, model parameters—half of the mass variance, range and threshold or quasi-total variance—were also calculated **(Ozgoz, E., et al., 2013).** The sum of half of the variance (C0 + C) was determined. Half of the mass variance is the variance at zero distance; Threshold is the distance between measurements at which one value of a variable does not affect adjacent values; The range is the distance at which the values of one variable become spatially independent of the other. The geostatistical analysis presented different models for the spatial distribution and levels of spatial dependence of the studied soil properties. As we have seen, the ranges of spatial dependencies show great variance. Knowing the impact range of different soil properties allows an individual to create an independent database to do the classical statistical analysis. It also helps in deciding where to return the sample if needed and in designing further field trials to avoid spatial dependency.

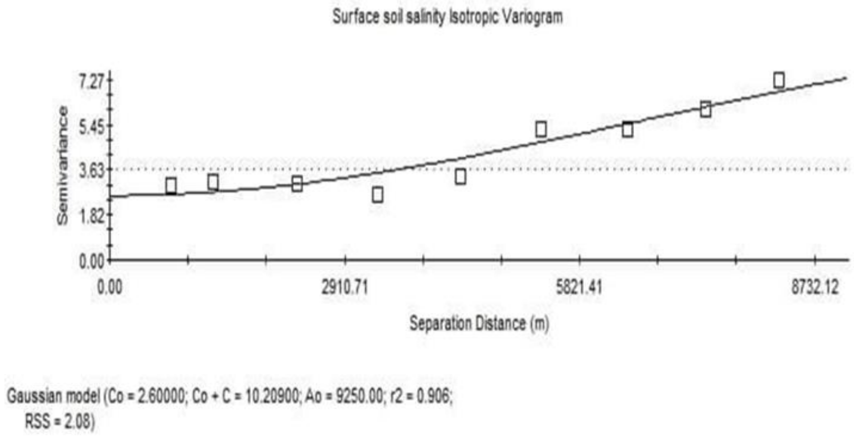


Fig. (1): Isotropic semivariogram of soil salinity (EC) in the surface soil samples

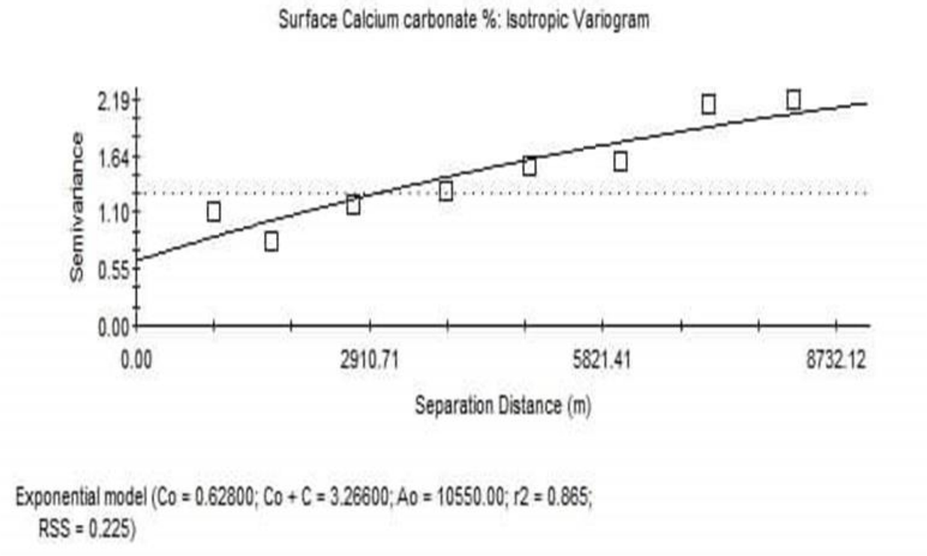


Fig. (2): Isotropic semivariogram of calcium carbonate (CaCO3) in the surface soil samples

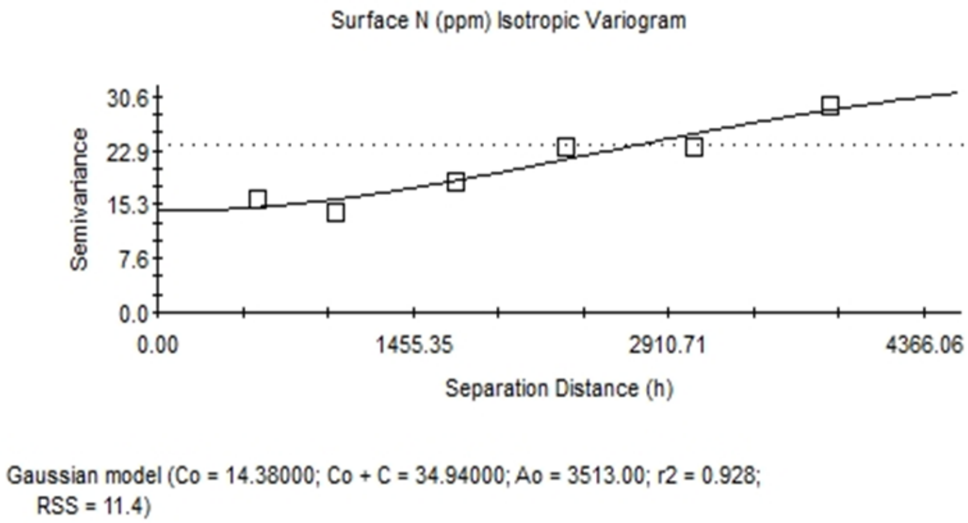


Fig. (3): Isotropic semivariogram of nitrogen (mgkg-1) in the surface and subsurface soil samples

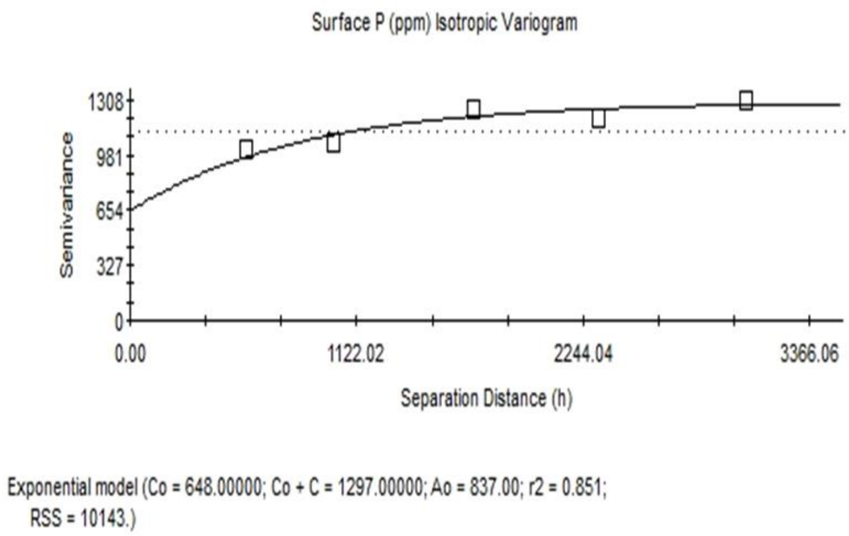


Fig. (4):): Isotropic semivariogram of phosphorus (mgkg-1) in the surface soil samples

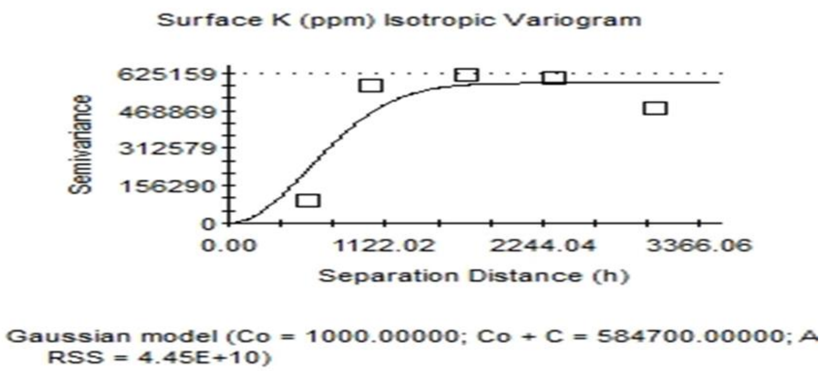


Fig. (5):): Isotropic semivariogram of potassium (mgkg-1) in the surface soil samples

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الملخص العربي

التوزيع المكاني ورسم الخرائط لبعض خصائص الاراضى الجيرية المتأثرة بالاملاح بمنطقة غرب النوبارية ، مصر باستخدام تقنيات التحليل الجيوإحصائي ونظم المعلومات الجغرافية

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توفر الإحصاء الجيولوجي أدوات وصفية لوصف التوزيع المكاني لخصائص التربة ، وتهدف هذه الدراسة إلى التحقق من التباين في بعض خصائص التربة في منطقة غرب النوبارية في مصر. ويغطي أجزاء من محافظتي الإسكندرية والبحيرة بمساحة إجمالية حوالي 5000 فدان. أوضحت النتائج أن التربة المدروسة تتميز بقوامها الرملي الطيني إلى الطمي الرملي في معظم العينات. ومع ذلك ، فإن إجمالي الأملاح الذائبة EC ، كما يعبر عنها بالموصلية الكهربائية ونسبة امتصاص الصوديوم SAR تشير إلى أن معظم الترب المدروسة تتميز بقيم متوسطها إلى مرتفع EC و SAR تراوحت قيم EC بين 0.78 و 9.69 ديسيسمنز / متر ، وقيم معدل SAR تتراوح من 1.03 إلى 10.31 ، وتراوحت إجمالي محتوى كربونات الكالسيوم بين 12.12 و 64.68٪. المواد العضوية تتراوح بين 0.18 و 1.36٪. تراوحت قيم الأس الهيدروجيني بين 7.50 و 8.40. تراوحت كميات الرمل والطمي والطين من 66.36 إلى 85.36 و 5.00 إلى 18.00 و 9.64 إلى 20.24٪ على التوالي. كما أظهرت نتائج تحليل التباين المكاني للتربة لبعض خصائص التربة أن التباين في ملوحة التربة والنيتروجين المتاح والبوتاسيوم المتوفر يتبع النموذج Gaussian في طبقات التربة السطحية ، ولكنه يتبع النموذج Exponential لطبقات التربة السطحية لكل من كربونات الكالسيوم الكلية والفوسفور المتاح. تم استخدام هذه النماذج لرسم خرائط التوزيع المكاني والرسوم البيانية ثلاثية الأبعاد لخصائص التربة السابقة ، وبالتالي لإنشاء خرائط التربة من خلال تقنيات نظم المعلومات الجغرافية (GIS).