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SPATIAL DISTRIBUTION OF SOME SOIL PHYSIOCHEMICAL PROPERTIES IN KALABSHOW FARM USING GEOSTATISTICS

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ABSTRACT

Geostatistics provides valuable tools to characterize the spatial distribution of soil properties. Kriging techniques rely on the spatial dependence between observations to predict attribute values at un-sampled locations. These techniques were used to study the spatial distribution of some soil physiochemical properties at the experimental farm of Mansoura University, Kalapshow, Bilqas District, Dakahlia Governorate, Egypt. Ordinary Kriging (OK) was used to surface interpolate soil clay, available water, EC, bulk density, soil organic matter (SOM), soluble K, exchangeable K and available K.

Soil clay in the studied area varied from 1.23 to 9.17%. These values were associated with the conventional management practices of adding clay to these sandy textured soils. Available water was very low and varied from 6.49 to 9.87%. This is expected due to the relatively low clay content, and consequently low water holding capacity. Soils in the studied were non-saline, where EC values ranged between 1.09 and 3.09 dSm^{-1}. Bulk density values ranged from 1.33 to 1.54. The pH values ranged from 8.03 to 8.19 in saturation soil paste. SOM was low and ranged between 0.35 and 0.96%. Soluble K varied from 0.12 to 0.26 $meq.L^{-1}$, whereas exchangeable k varied from 0.12 to 0.55 Cmol.kg-1. Studied soils ranged between low (52 ppm) and moderate (178 ppm) in available K. Clay content had highly significant correlations ($p=0.001$) with exchangeable k, available k, available water, and SOM ($r= 0.93$, 0.91, 0.81, and 0.55, respectively).

It could be concluded from the spatial distribution of these physiochemical properties that higher values of available water, EC, SOM, and the three forms of soil k were highly associated with those areas that have high contents of clay, whereas lower values were related to areas higher in sand.

INTRODUCTION

Spatial interpolation techniques have been widely used in soil science for estimating the value of variable at un-sampled locations. They also used to assess the spatial patterns of variations for a number of soil properties at a range of scales and with different sizes of sampling grids. These techniques vary from simple ones such as linear and multiple regressions to more complicated ones like Kriging and co-kriging (Kollias *et al.*, 1999, El-Menshawy *et al.*, 2006)).

Kriging is a geostatistical spatial interpolation method that derives predicted values based on the distance between points in space and the variation between measurements as a function of distance. Ordinary kriging is a version of kriging that assumes the mean is constant but unknown across the spatial domain of interest (EPA, 2004). Kriging is commonly used in soil science to predicting soil properties such as EC, pH, Clay, saturation percent, available water, available NPK, exchangeable cations, CEC and $CaCO_3$ (Goovaerts 1997, Chilès and Delfiner 1999, Stein, *et al.*, 1999, and Davis 2002). Ramadan and El-Fayoumy (2005) used Kriging map to indicate the inherited spatial micro-variability distribution of pH and EC. Najafi Ghiri *et al.* (2010) studied the spatial distribution of the different forms of soil potassium and their relationships with clay mineralogy and other soil properties by using ordinary Kriging. The obtained relationships were very important for understanding K equilibrium and K fertility status of soils. Salem *et al.* (2008) used Kriging to develop interpolation maps of soil salinity and calcium carbonate content.

The objectives of this work are to develop the spatial distribution maps of some soil physiochemical properties (clay, available water, Ec, bulk density, SOM, soluble K, exchangeable K and available K) in Kalabshow farm using ordinary Kriging and to study the relationships between these properties and soil management practices.

MATERIALS AND METHODS

This study was carried out at Mansoura University Agricultural Experimental Station, Kalapshow farm, Bilqas district, Dakahlia Governorate, Egypt. Studied area covers about 0.168 km^2 (40 Feddan) and located between these coordinates 31° 23′ E & 31° 25′ N. This area is classified into four plots according to their management practices (Plots 1 and 2 have no additions of clay, Plot 3 has intensive additions of clay, whereas Plot 4 has moderate additions of clay). Surface elevation varies from 1 to 2 m above sea level and slope ranges between 0 and 1%. Soils in the studied are developed on stable sand dunes. Accordingly, they are classified as sandy, mesic, xeric torripsamments (El-Hamdi *et al*, 2010).

A grid soil sampling technique was applied in collecting soil samples from the studied area. A grid size was 50 x 50 m^2 (about 0.5 feddan) and a total of 62 soil samples were collected (Fig 1). Coordinates of soil samples were recorded using the Global Positioning System (GPS). Soil samples were air-dries, crushed to pass through 2-mm sieve, sieved, and stored for soil physical and chemical analyses.

Mechanical analysis was carried out using the pipette method as described by Piper (1950). Bulk density was determined by the methods described by (Dewis and Freitas, 1970).Total carbonate was estimated volumetrically using Collins Calcimeter and calculated as calcium carbonate as described by Piper (1950). Soil reaction (pH) was measured in saturated soil paste using combined electrode pH meter as mentioned by (Jackson, 1967). Soil salinity was measured in 1:5 soil water extract (Hesse, 1971), then convert EC of 1:5 soil water extract to EC of soil saturation extract by correlation between them (Kaoud, 1979). Soluble cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions ($CO_3^{=}$, HCO_3^{-}, Cl^{-} and $SO_4^{=}$) were measured in 1:5 soil water extract as described by Jackson (1967). Available potassium was determined by extracting soil with 1.0 N ammonium acetate at pH 7.0 as described by (Knudesen *et al.*, 1982). Soil organic matter was determined by Walkley and Black method as described by Hesse (1971).

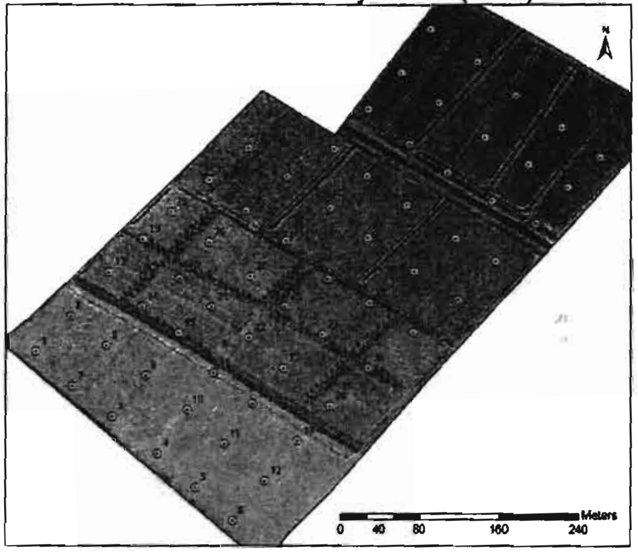

Fig 1: Spatial distribution of soil samples in the studied area.

Kriging was used in this study to estimate the value of a random variable Z at one or more un-sampled points or locations, from more or less sparse sample data on a given support say: **{z(x1), . . . , z(xN)} at {x1, . . . ,xN}.**

Different kinds of Kriging methods exist, which pertains to the assumptions about the mean structure of the model: **E[Z(x)] = μ(x)**
Z(x) is not intrinsically stationary. Having a deterministic model for μ(x), then Z(x)−μ(x) is intrinsically stationary (or even weakly stationary).

Ordinary Kriging is the most common type of Kriging. It was used in this work to interpolate surfaces of soil clay, available water, EC, bulk density, SOM, soluble K, exchangeable K and available K. The underlying model assumption in ordinary kriging is: **E[Z(x)] = μ**
With μ unknown, the model for Z(x0) is:

$$Z(x0) - \mu = \sum_{i=1}^{N} \lambda i \,(Z(x_i) - \mu) + E\,(x_0) \qquad \text{Or} \qquad Z(x0) = \sum_{i=1}^{N} \lambda i \,(Z(x_i) + \mu(1 - \sum_{i=1}^{N} \lambda i\,) + E\,(x_0)$$

We filter the unknown mean by requiring that the Kriging weights sum to 1, leading to the ordinary kriging estimator:

$$Z(x0) = \sum_{i=1}^{N} \lambda i \,(Z(x_i) + E\,(x_0) \text{ subject to } \sum_{i=1}^{N} \lambda i = 1$$

The Geostatistical analyst in ArcGIS 9.3 (ESRI, 2008) was used to develop the semivariogram between each pairs of points versus their separation distances. This semivariogram was used in predicting the studied soil physiochemical properties.

RERSULTS AND DISCUSSION

Soil properties of the studied area:-

Data in Table 1 and 2 represent means of soil physical and chemical characteristics of the four plots in the studied area. Soils in all plots were considered non-saline (EC value ranged between 1.09 and 3.09 dSm^{-1}). Values of soil pH varied from 8.03 to 8.19 in soil paste. Particle size distribution data represented in Table 2 revealed a prominent sandy soil textures in the studied area, where sand particles were more than 70% of the studied samples. The highest clay content was recorded in plot 3, whereas the lowest content was in plot 1. Soil organic matter was low (0.35 to 0.96%) in the studied soils. The highest SOM value was in plot 3, whereas the lowest value was in plot 4. Soils were considered non calcareous, where total CaCO$_3$ was less than 6 %. Bulk density varied from 1.33 to 1.54. Obtained data also revealed that the studied soils ranged between poor and moderate in available K according to Hamissa *et al.* (1993). Available water was very low, which ranged between 6.49 to 9.87%. This is expected due to the relatively low clay content, and consequently low water holding capacity.

Table 1: Electrical conductivity (EC, dSm^{-1}), soluble cations and anions (meq. L^{-1}) in 1:5 soil: water extract, and pH in saturation soil paste at the studied areas

Soil Plot	EC (dSm^{-1}) in sp	EC (dSm^{-1}) (1:5)	pH	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO$_3^{--}$	HCO$_3^{-}$	Cl^{-}	SO$_4^{--}$
Plot 1	1.09	0.40	8.13	0.59	0.41	2.72	0.12	0.00	0.89	2.75	0.20
Plot 2	1.74	0.57	8.19	0.50	0.51	4.51	0.17	0.00	1.22	4.30	0.17
Plot 3	2.51	0.78	8.12	0.48	0.59	7.35	0.21	0.00	2.21	5.46	0.96
Plot 4	3.09	0.93	8.03	0.71	1.51	7.54	0.26	0.00	1.06	8.50	0.45

Table 2: Exchangeable K, available K, SOM, CaCO$_3$, Bulk density, available water, Particle size distribution and texture classes, of study areas

Soil Plot	Ex. K (Cmol. kg-1)	Av.K ppm	SOM (%)	CaCO$_3$ (%)	Bulk density	Available water (%)	Particle size distribution				Texture
							Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
Plot 1	0.12	52.45	0.52	0.12	1.54	7.32	35.56	58.49	4.72	1.23	Sandy
Plot 2	0.23	86.35	0.75	0.22	1.49	7.04	37.73	53.58	5.83	2.87	Sandy
Plot 3	0.55	177.51	0.96	0.41	1.33	9.87	36.69	43.45	10.68	9.17	Sandy
Plot 4	0.15	90.08	0.35	0.15	1.54	6.49	41.87	51.70	3.86	2.58	Sandy

Spatial distribution of soil physiochemical properties:

The spatial distribution of soil clay is illustrated in Figure 2. This figure reveals obvious variations in clay content within the studied area. Higher clay contents were observed in the middle part of the studied area (Plot 3), whereas lower values were watched near the northern and the southern parts of the studied area. This could be doe to continuous additions of clay soils to this plot of the studied area. This is considered one of the most common management practices in reclamation of these sandy-textured soils.

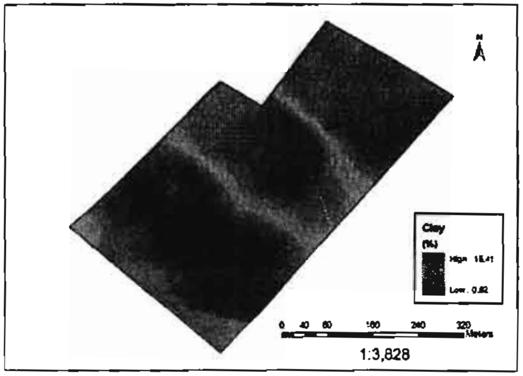

Fig 2: Spatial distribution of clay in the studied area.

Figure 3 illustrates the spatial distribution and variations of available water in the studied area. In general, available water was low in soils of the studied area. However the surface interpolation revealed variations in available water from one part to another. Higher values were observed in plot 3, which also is associated with the higher clay contents in that plot. Lower values where existed in the three other plots, which have higher contents of sand. Similar results were obtained by Salem *et al.* (2008).

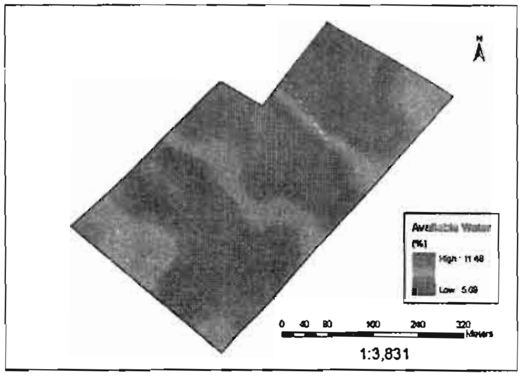

Fig 3: Spatial distribution of available water in the studied area.

Distribution of soil organic mater is illustrated in Figure 4. It indicates lower contents of SOM in the studied area. However the content of SOM varied among soil plots. Plot 3 had the highest values when compared with the other plots. The highest values could be associated with the high clay content in plot 3. On contrary, the lowest values could be related to high sand content; which results in higher decomposition rates of SOM. SOM content in plot 1 and plot 4 was lower. Higher Values where existed in the plots 2 and 3 may be due to clay distribution in these plots.

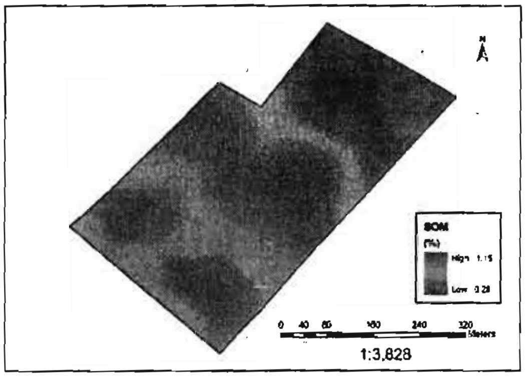

Fig 4: Spatial distribution of SOM in the studied area.

Figure 5 illustrates the spatial distribution and variations of soil salinity in the studied area. The highest EC values were observed in plots 3 and 4, whereas the lowest values were observed in plots 1 and 2. The higher values in plot 3 could be related to the high clay content in that plot, irrigation with low quality water, poor drainage, and higher levels of ground water. In plot 4, the high EC values could be due to the presence of a clay pan at about 30 cm from the surface resulted from the past additions of clay soils. It could be also due to the higher levels of ground water, where this plot is close to the irrigation canal. These results are agreement with those obtained by (Ismail *et al.* 2005).

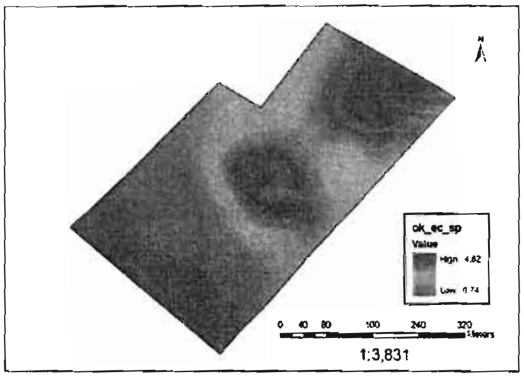

Fig 5: Spatial distribution of EC in the studied area.

Variations in soil bulk density within the studied area are represented in Figure 6. Lower values were observed in plot 3, which could be associated with the higher contents of clay and SOM in that area. On the other hand, lower values were noticed in plots 1, 2 and 3, which were higher in their sand content.

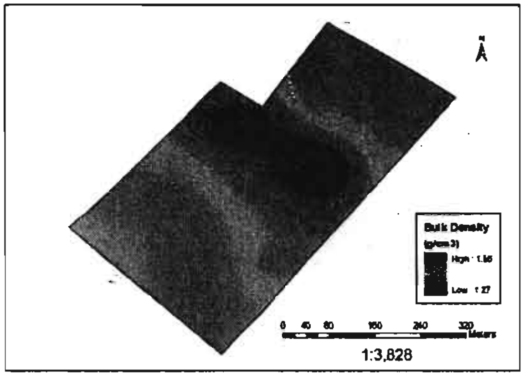

Fig 6: Spatial distribution of soil bulk density in the studied area.

Distribution of exchangeable K in the studied area is represented in Figure 7. This figure revealed obvious variations in values of exchangeable K within the studied area. Higher values were observed in the middle part of the studied area (Plot 3), whereas lower values were watched near the northern and the southern parts of the studied area. The higher values could be associated with the higher contents of both soil clay and SOM, due to their higher cation exchange capacities. The lower values where connected to these plots higher in sand content. These results are confirmed by those obtained be El-Agrodi *et al.* (1998a).

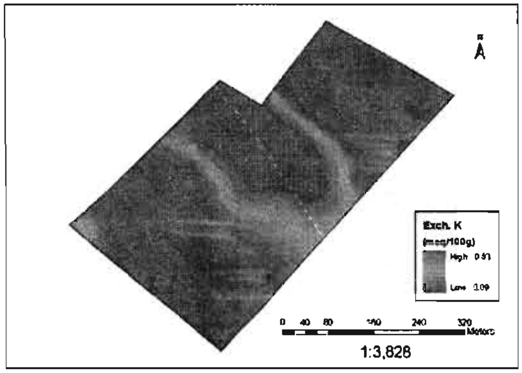

Fig 7: Spatial distribution of exchangeable K in the studied area.

Figure 8, illustrates the spatial distribution and variations of Soluble K in the studied area. Higher values were observed in plots 3 and 4, which could be associated with the higher EC values as represented in figure 5. This might be supported by the highly significant correlation between EC values in saturation paste extract and soluble K ($r= 0.68$, $p= 0.001$). Lower values were noticed in the southern plots.

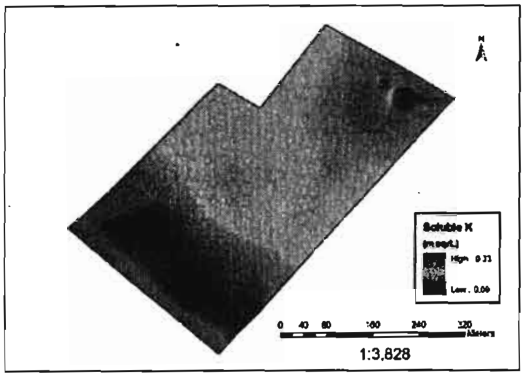

Fig 8: Spatial distribution of Soluble K in the studied area.

Spatial distribution of available K in the studied area is demonstrated in figure 9. There were obvious variations in available K content within the studied area. Higher values were observed in the middle part of the studied area (Plot 3), whereas lower values were watched near the northern and the southern parts of the studied area. These changes in values of available K could be due to the variation in clay contents and SOM within the studied area.

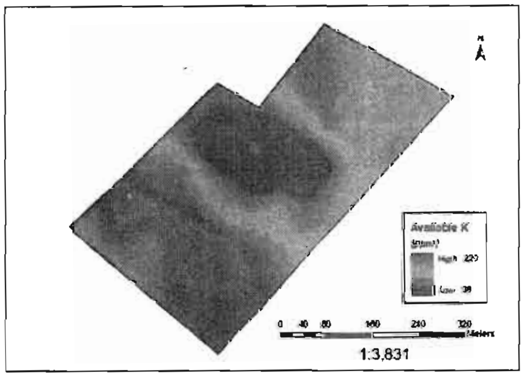

Fig 9: Spatial distribution of Available K in the studied area.

Liner correlation between soil properties:

Highly significant correlations (p=0.001) were found between clay content and exchangeable and available k (Figure 10), available water, and SOM (r= 0.93, 0.91, 0.81, and 0.55, respectively). SOM was highly correlated with exchangeable, available k, and available water (r=0.68, 0.61, and 0.57, respectively). Silt was highly correlated with both exchangeable and available k (r=0.80, and 0.71, respectively). El-Agrodi *et al.* (1998b) reported higher correlations between clay fraction and exchangeable and available forms of K in Dakahlia soils. Similar results were also reported by Idigbor and *et al.* (2009), Najafi Ghiri *et al.* (2010), and Salem *et al.* (2008). They also reported higher values of soluble k in salt-affected soils. Clay was highly correlated with EC values (r=0.35, p=0.005). This is considered one of the adverse effects of adding clay to sandy soils, especially at higher water table or poor drainage.

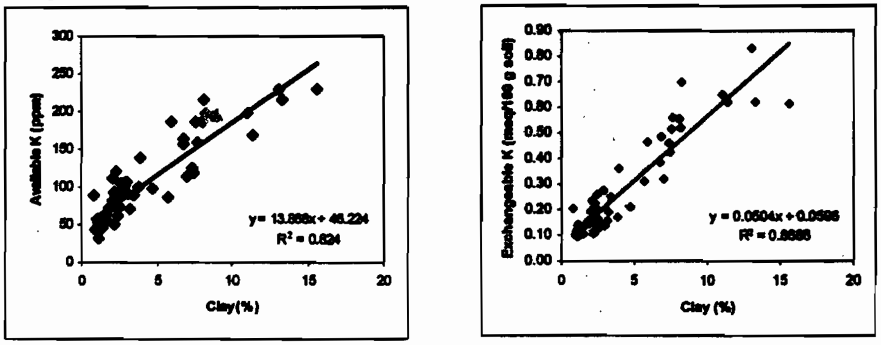

Figure 10. Correlation between Clay content and available and exchangeable K in the studied Soils.

Conclusions:

It could be concluded that ordinary Kriging could be a powerful tool in developing the spatial interpolation maps of soil physiochemical properties. It also can illustrate the spatial variations in each soil property within the studied area, which could help in linking these variations with other soil properties or management practices. It was found that continuous additions of clay soils as one of the common management practices in reclamation of sandy-textured soils in Egypt were associated with the variations in spatial distribution of most soil properties in the studied area such as exchangeable k, available k, available water, and SOM. Highly significant correlations were also found between clay content and exchangeable k, available k, available water, and SOM in the studied area. Significant correlation was also found between clay content and soil salinity (EC values), which is considered one of the undesirable impacts of adding clay to poorly drained sandy soils.

REFERENCES

Chilès, J. P. and P., Delfiner, 1999. Geostatistics: modeling spatial uncertainty.Wiley series in probability and statistics. John Wiley & Sons, New York

Davis, J.C., 2002. Statistics and data analysis in geology. John Wiley & Sons,New York.

Dewis, J. and F. Freitas 1970. Physical and Chemical Methods of Soil and Water Analysis. Soil Bultin 10, FAO, Rome.

El-Agrodi, M.W., El-Hadidi, E. M., Hammad, S.A., Elnaggar; A.A. 1998a. Potassium Status in Dakahlia Governorate Soils. J. Agric. Sci. Mansoura Univ., 23(5): 2315-2323.

El-Agrodi, M.W.; E. M., El-Hadidi; S.A., Hammad; Elnaggar; A.A. 1998b. Potassium Supplying Power of Dakahlia Governorate Soils. J. Agric. Sci. Mansoura Univ., 24(2): 861-872.

El-Hamdi, Kh. H.; M. Y. EL-Arqan; A. A. Elnaggar and M. M. M. Omar, 2010. Application of remote sensing and geographic information data in developing soil classification maps of some soils in Nile-delta. J. Soil Sci. and Agric. Engineering, Mansoura Univ., 1 (51): 421-423.

El-Menshawy, A. B. and H. A. yehia 2006. Geostatistical analysis of some soil properties using collocated cokriging, of El-Hamam experimental research farm, west Alexandria city, Egypt. J. Agric. Sci. Mansoura Univ. 31 (3): 1761-1777.

EPA, 2004. Developing Spatially Interpolated Surfaces and Estimating Uncertainty. U.S. ENVIRONMENTAL PROTECTION AGENCY, Research Triangle Park, NC 27711.

ESRI, 2008. ArcGIS Geostatistical Analyst Tutorial (ArcGIS®9). Printed in the United States of America.

Goovaerts, P., 1997. Geostatistics for natural resources evaluation. Applied Geostatistics. Oxford University Press, New York

Hamissa, M. R.; A. Serry, and N. M. El-Mowelhi 1993. Fertilizer management for corn in Egypt. Soil and Water Research Istitute, Cairo, Egypt, P. 36.

Hesse, P. R. 1971. "A Text Book of Soil Chemical Analysis". John Murry (Publishers) Ltd, 50 Albermarle Street, London.

Ismail, H.A., M.H. Bahnassy, O.R. Abd El-Kawy (2005). Integrating GIS and modelling for agricultural land suitability evaluation at East Wadi El-Natrun, Egypt. Egyptian J. of Soil Sci. 45(3) 297-322.

Jackson, M. L. 1967. "Soil Chemical Analysis". Printice Hall of India, New Delhi. PP. 144-197.

Kaoud, E. E. 1979. Formation and diagnosis salt affected soils in the eastern areas of the delta. M. Sc. Thesis, Fac. of Agric., Mansoura Univ.

Knudesen, D., G. A. Peterson and P. F. Partt 1982. Lithum, Sodium and Potassium. Chapter 13 in Method of Soil Analysis. Part. 2. Chemical and Microbiological Properties Agronomy No. 9 2nd Ed. Soil Sci. Amer. Madison, Wis.

Kollias, V. J.; D. P. Kalivas, and N. J. Yassogolu 1999. Mapping the soil resources of a recent alluvial plain in Greece using fuzzy sets in a GIS environment. Eurpean J. Soil Sci., 50, 261-273.

Ldigbor, C.M.; D. O. Asawalam; E. U. Onweremadu; and B. N. Ndukwu 2009. Potassium quantity-intensity relationship of fauna modified soils of abia state. International J. of Sustainable Agri. 1 (2): 49-52.

Najafi Ghiri, M.; A. Abtahi; F. Jaberian; and H.R. Owliaie 2010. Relationship between soil potassium forms and mineralogy in highly calcareous soils of southern iran. Australian J. of Basic and Applied Sci. 4(3): 434-441.

Piper, C. S. 1950. "Soil and Plant Analysis" . Inter. Science Publishers Inc. New York.

Ramadan H. M. and M. E. El-Fayoumy 2005. Spatial and temporal variability of soil fertility for crop management under calcareous soil conditions. Egypt, J. Soil Sci. 45 (4): 461-480.

Salem, M.Z.; G. W. Ageeb; and I.S. Rahim 2008. Land Suitability for Agricultural of Certain Crops in Al-bostan Area, Egypt. Research Journal of Agriculture and Biological Sciences, 4(5): 485-499.

Stein, A., Meer, F.v.d. and Gorte, B.G.F. (Editors), 1999. Spatial statistics for remote sensing. Kluwer Academic, Dordrecht.

التوزيع المكاني لبعض خواص التربة الفيزيائية والكيميائية في مزرعة قلابشو باستخدام التحليل الجيوإحصائي.

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تقدم الإحصاء المكانية أدوات قيمة لتوصيف التوزيع المكاني لخواص التربة. تعتمد طرق Kriging علي الارتباط الفراغي بين العينات للتنبؤ بقيم خواص التربة تحت الدراسة في مواقع لم يؤخذ منها عينات. تم استخدام هذه الطريقة لدراسة التوزيع الفراغي لبعض خواص التربة الطبيعية والكيميائية في محطة تجارب كلية الزراعة جامعة المنصورة الزراعية بقلابشو – مركز بلقاس.

إستخدمت طريقة Kriging لدراسة بعض خواص التربة مثل محتوي الطين ، الماء الميسر، درجة الملوحة، الكثافة الظاهرية، مادة الأرض العضوية، البوتاسيوم الذائب، البوتاسيوم المتبادل و البوتاسيوم الصالح.

وأشارت النتائج إلي أن نسبة الطين كانت (١,٢٣- ٩,١٧%) وترتبط هذه القيم مع الممارسات الزراعية التقليدية والتي تتمثل في إضافة الطين للأراضي الرملية حديثة الاستصلاح. وكان محتوي الماء الميسر منخفض (٦,٤٩ – ٩,٨٧%) كنتيجة متوقعة لانخفاض محتوي التربة من الطين وبالتالي انخفاض السعة التشبعية. أوضحت النتائج أن منطقة الدراسة غير ملحية حيث كان التوصيل الكهربي للتربة (١,٠٩ – ٣,٠٩ ديسيمنز /سم). وكانت قيم الكثافة الظاهرية (١.٣٣ – ١.٥٤). وكانت قيم تفاعل التربة (٨,٠٣ – ٨,١٩). وكان محتوي التربة من المادة العضوية (٠,٣٥ – ٠,٩٦ %). وكانت قيم البوتاسيوم في محلول التربة (٠,١٢ – ٠,٢٦ ميلليمكافئ/لتر) أما قيم البوتاسيوم المتبادل فتراوحت بين (٠,١٢ – ٠,٥٥ ميلليمكافئ/١٠٠جم تربة) وقيم البوتاسيوم الصالح في منطقة الدراسة كانت منخفضة إلي متوسطة (٥٢ : ١٧٨ مللجرام /كجم) علي التوالي.

كان ارتباط محتوي الطين عالي المعنوية (p= ٠,٠٠١) مع البوتاسيوم المتبادل وكذلك البوتاسيوم الصالح والماء الميسر والمادة العضوية ٢ = ٠,٩٣ ، ٠,٩١ ، ٠,٨١ علي التوالي. ويمكن الاستنتاج من التوزيع الفراغي لخواص التربة الفيزيائية والكيمائية وجود أرتباط كبير بين القيم العالية من الماء الميسر، التوصيل الكهربي ، مادة الأرض العضوية و الأشكال المختلفة للبوتاسيوم مع المناطق ذات المحتوي العالى من الطين بينما أرتبطت القيم المنخفضة لهذه الخصائص بالمناطق ذات المحتوي العالي من الرمل.

قام بتحكيم البحث

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