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# SPATIAL VARIABILITY OF SOME SOIL PROPERTIES IN SAHL AL-HUSSAINIYAH, SHARKIA GOVERNORATE, EGYPT

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**ABSTRACT:** Sustainable soil management with appropriate understanding of soil characteristics is vital in maintaining and improving soil fertility. The objectives of the present study is to characterize the spatial variability across a soil for selected using GIS technique. A total of 120 geo-referenced representative soil samples (from 0 to 0.60 m depth) were collected from Sahl Al-Hussainiyah, Sharkia Governorate, Egypt. Analyses included pH, $EC_e$, $CaCO_3$, soil organic matter (OM), available N, P and K, cations exchange capacity (CEC) and bulk density (BD). Spatial distribution pattern varies from moderate to strong. The best fit semivariogram model of $EC_e$, K and BD was stable model, whereas K-Bessel model was the best fit model of pH, OM and CEC. With the exponential model, the best fit was with $CaCO_3$, N and P. According to the spatial distribution map, five zones were identified, where the study area was classified to < 7.17, 7.17 to 7.41; 7.41 to 7.66; 7.66 to 7.89, and > 7.8 for pH, < 6.70, 6.71 to 8.17; 8.18 to 9.73; 9.74 to 11.4, and > 11.5 $dSm^{-1}$ for EC, < 2.3, 2.31 to 2.92; 2.93 to 3.76; 3.77 to 4.52, and > 4.53% for $CaCO_3$, < 0.43, 0.44 to 0.52; 0.53 to 0.61; 0.62 to 69, and > 0.70% for OM, < 30.3, 30.3 to 37.9, 37.9 to 45.6, 45.6 to 52.6, and > 62.6 mg $kg^{-1}$ for N, < 1.61, 1.62 to 2.43; 2.44 to 3.31; 3.32 to 4.30, and > 3.41 mg $kg^{-1}$ for P. < 103, 104 to 113; 114 to 124; 125 to 132, and > 132 mg $kg^{-1}$ for K, < 43.2, 43.2 to 46.8; 46.8 to 50.8; 50.8 to 55.8, and > 55.8 cmolc $kg^{-1}$ for CEC and < 1.27, 1.28 to 1.32; 1.33 to 1.39; 1.40 to 1.51, and > 1.52 Mg $m^{-3}$ for BD. Thus, this methodology can be used succsseffly in Spatial Variability of some soil properties.

**Key words:** Precision agriculture, spatial distribution, GIS, Sahl Al-Hussainiyah.

## INTRODUCTION

Sustainable soil management with proper understanding of soil characteristics make a difference in maintaining and improving soil fertility and avoiding degradation, (**Thapa and Yila, 2012; Zhao *et al.*, 2013**). Due to effects of soil physical, chemical and biological processes in the soil system along with human and animal activities, marked soil characteristics occur among soils differ (**Goovaerts, 1998**). The main key to site-specific soil management for sustainable crop production by addition of nutrients is proper understanding of the special variation of soil characteristics (**Behera and Shukla, 2015; Brevik *et al.*, 2016; Bogunovic *et al.*, 2017; Shukla *et al.*, 2017**). Spatial soil characteristics could be assessed using geostatistical methods like ordinary kriging (**Mueller *et al.*, 2003; Behera *et al.*, 2018**). **Saito *et al.* (2005)** revealed that values in un-sampled locations can be predicted through geospatial modelling techniques by studying the spatial correlation analysis between the estimated and sample points and reduced estimation errors and related costs. classification the heterogeneous soil into different zones having homogeneous characteristics by delineation site of management zone (MZ) of soil is a technique to address soil heterogeneity (**Ortega and Santibáñez, 2007; Xin-Zhong *et al.*, 2009; Peralta *et al.*, 2015**). Geo-statistics principal component analysis (PCA) and cluster analysis are methods used by several researchers to delineate soil MZs in agroecosystems including different crops for site specific soil management (**Davatgar *et al.*, 2012; Tripathi *et al.*, 2015; Nawar *et al.*, 2017; Shukla *et al.*,

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**2017**). The concept of "management zone" was developed in response to major soil variation is mainly intended to improve agricultural inputs (**Ali and Ibrahim, 2016**). The homogeneous sub areas in a field which have similar yield limiting factors called "site-specific management zones" (**Doerge, 1999; Khosla and Shaver, 2001**). The main objective of site-specific management is managed variability of soil spatially by adding inputs according to the site-specific requirements of a specific soil and crop (**Fraisse e*t al.*, 2001**). In theory, the arable field can be classified into management zones that reflect the general difference in soil characteristics using management zone delineation technique. There are considerable attempts to delineate such management zones (**Ali and Ibrahim, 2016**). Many studies have attempted to describe the association between topography of arable fields and soil nutrient content such as nitrogen (**Bruulsema *et al.*, 1996; Cassel *et al.*, 1996**) as well as differences in yield (**Verity and Anderson, 1990**). The objectives of the present study is characterizing spatial variability across a soil for selected soil properties using GIS technique.

# MATERIALS AND METHODS

## Study Area and Soil Sampling

The study was conducted in Sahl Al-Hussainiyah, Sharkia Governorate, Egypt, bounded by 31°47′30″ and 32°11′30″ E and 30°44′30″ and 31°11′30″ N (Fig. 1). Based on Port Said and Ismailia meteorological station, the maximum temperatures varied from 31.9 to 37.1°C in August; and the lowest varied between 9.7 to 13.1°C in January with an annual average of 22.5°C and 22.8°C, respectively and a wide difference between summer and winter. The annual precipitation varied from 33.3 to 73.3 mm, with no even distribution. The highest precipitation was in November and December (7.7 to 18 mm). The relative humidity varied from 58 to 72%. The wind velocity ranged between 14.2 and 18.7 km $hr.^{-1}$ at Port Said, recorded in September and March, respectively. In Ismailia it ranged between 10 and 17.1 km $hr.^{-1}$ in November and March, respectively.

A total of 120 geo-referenced representative soil samples (from 0 to 0.60 m depth) were collected using hand auger and prepared for analysis (air-dried, crushed and passed through a 2 mm sieve). GPS devices were used to record the latitude and longitude of each sampling point collected from five villages *Viz*. Tariq-Bin-Ziyad, Al-Slah, Khaled-Bin-Walid, El-Azhar and Al-Rowad. The sampling areas were areas under reclamation by excessive leaching processes because of the high salt concentrations in soil profiles. Soil pH, EC, $CaCO_3$, OM, available N, P and K, CEC and BD were analyzed according to **Richards (1954) and Van Reeuwijk (2002)**.

## Statistical, Geostatistical, Principal Component and Cluster Analysis

Descriptive statistics revealing, minimum, maximum, mean and standard deviation, were done using XLSTAT software version 2016. Normality distribution of soil properties were tested using shapiro-wilk test. Relationships between pairs of soil properties were done through Pearson correlation coefficient. ArcGIS 10.4.1 software was used and semi-variogram was used to evaluate the spatial distribution pattern of each soil property. Semi-variogram was calculated using the following Eq. 1 (**Behera *et al.*, 2018**).

$$\gamma(h) = \frac{1}{2N(H)} \sum_{\alpha=1}^{N(h)} [Z(X_\alpha + h)]^2$$

Where γ(h), N (h), Z(xα) and Z(xα + h) represent semi-variance for the lag distance h, number of sample pairs separated by the lag distance h, measured value at αth sample location and measured value at point α + hth sample location, respectively.

Many criteria were used to evaluate different semi-variogram models like spatial dependence (SDC), Mean error (ME), Root-Mean-Square error (RMSE), Mean Standardized error (MSE), Root-Mean-Square Standardized error (RMSSE) and Average Standard Error (ASE). Generally, the best fit models was obtained for have mean error "ME", mean standardized error "MSE" and average standard error "ASE" values close to zero and root mean square error "RMSE" close to one (**Gundogdu and Guney, 2007**). **Cambardella *et al.* (1994)** reported that the

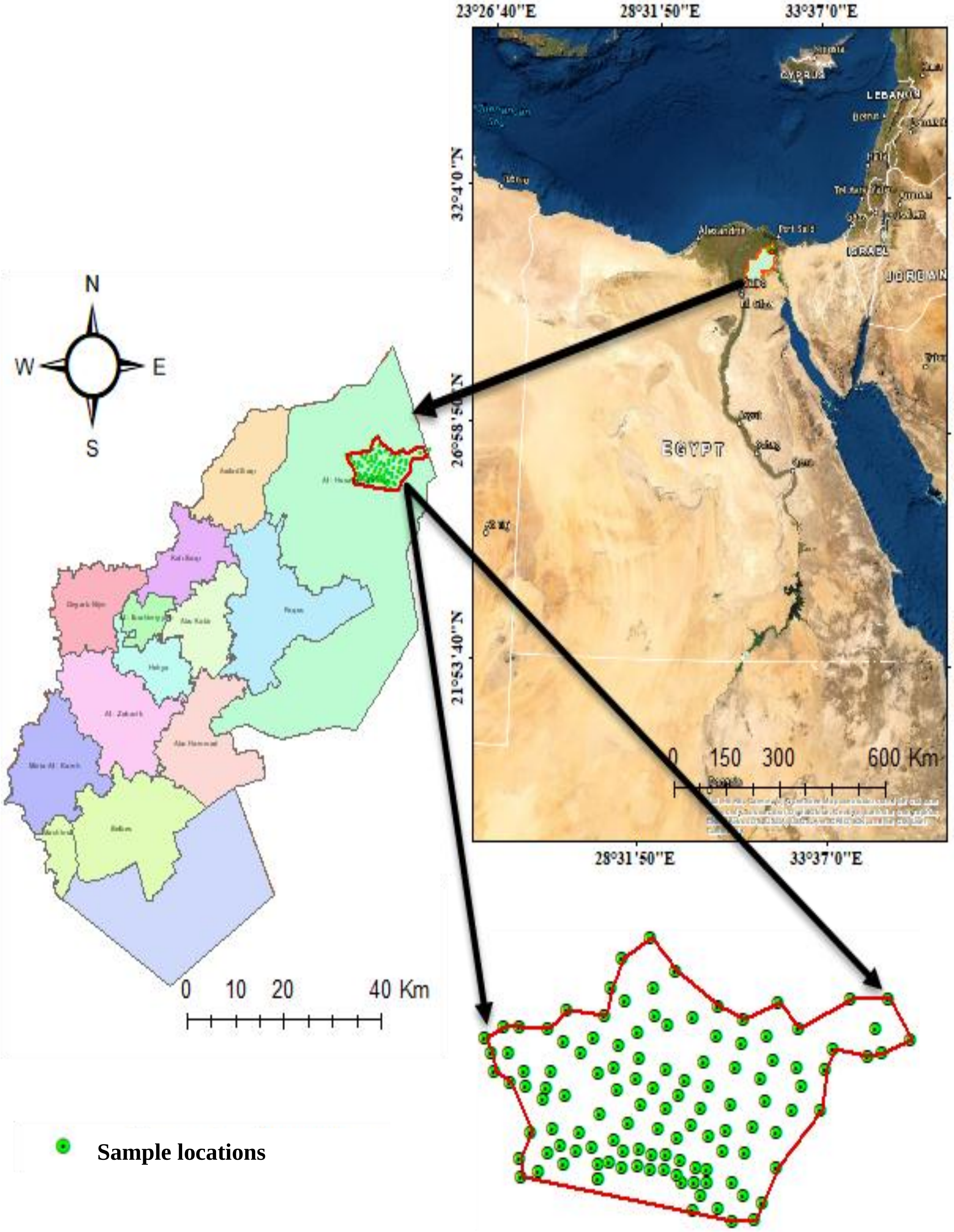


Fig. 1. Study area and locations of samples

semi-variogram model is based on nugget to sill ratio, spatial dependence (SDC), to strong (<0.25), moderate (0.25 – 0.75) and weak (> 0.75). The equations of criteria are as follows **(Johnston *et al.*, 1996)**.

$$\mathrm{ME} = \frac{1}{N}\sum_{i=1}^{N}[Z(x_i) - Z(\hat{x}_i)]$$

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}\frac{Z(x_i) - Z(\hat{x}_i)}{\sigma(i)}$$

$$\mathrm{ASE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\sigma(i)}$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z(x_i) - \hat{Z}(x_i)^2]}$$

$$\mathrm{RMSSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\{\frac{Z(x_i) - \hat{Z}(x_i)}{\sigma(i)}\}^2}$$

Where $\hat{Z}(x_i)$, $Z(x_i)$, n and σ are refer to the predicted value, the observed value, the number of values and standard error for location i, respectively.

Interpolation mapping was carried out using ordinary kriging method, a more reliable method than other methods based on MSE (**Meul and Van Meirvenne, 2003**), to determine the soil characteristics values at un-sampled locations. It is an unbiased predictor for the random process as well as reducing influence of outliers (**Triantafilis *et al.*, 2001**).

## RESULTS AND DISCUSSION

### The Studied Soil Properties

Table 1 show that statistics of soil properties varied greatly. The mean values of pH, EC, $CaCO_3$, OM, N, K, P, CEC and BD were 7.61±0.38, 9.43±3.79 dS $m^{-1}$, 3.55±1.61%, 0.6±0.15%, 42.39±13.95 mg $kg^{-1}$, 0.69±0.15 mg $kg^{-1}$, 2.59±1.59 mg $kg^{-1}$, 47.96±10.81 $cmol_c$ $kg^{-1}$ and 1.31±0.10 Mg $m^{-3}$, respectively. According to **Baruah and Barthakur (1997)**, the soil is located within the lower category for OM, N, K and P. Concerning soil pH the soil falls into the normal category, while it falls into the high category of salinity. Based on **FAO (1973)**, the soil is non-calcareous, where $CaCO_3$ is less than 15%. These findings agree with several studies, carried out in the same study area (**Nasef *et al.*, 2009; Shaban *et al.*, 2010; Ali *et al.*, 2014; Ibrahim *et al.*, 2015; Abd Elghany *et al.*, 2019; Mohaseb *et al.*, 2019)**. Although the great majority of soils in Egypt have pH exceeding 7 and up to 7.5-8.0 there are some areas have pH slightly below pH7.0 .This can be explained as follows, these areas are subject to excessive leaching therefore most cations are leached out of soil profile and the continued leaching leads to solodization and podsolization forming degraded soils (Soloth) (**Gedroiz, 1925; Kellog, 1934**). Solodization is marked by a loss of sodium and other basic cations and increased $H^+$ in the exchange complex, first in the near-surface horizons .The soils formed in the initial stages are called Solodized Solonetz (**Westin, 1953; Janzen and Moss, 1956; Whittig, 1959; Hallsworth and Waring, 1964; Miller and Pawluk, 1994; Anderson, 2010**). Soils formed in the final stages are called Soloth (**Kellog, 1934**), Solod (**Westin, 1953; Heck and Mermut, 1992; Miller and Pawluk, 1994; Zaidel'man *et al.*, 2010**) or Solodi (**Janzen and Moss, 1956; Whittig, 1959**). This indicates that the action of salinization and solonization in the Saline-Sodic soils has been replaced by the solodization process in the studied areas, with leaching of exchangeable bases, including $Na^+$, their replacement by $H^+$ and a consequent decrease in pH. These results agree with **Furquim *at al.* (2017)** who reported that leaching of exchangeable bases, and substitution with $H^+$ ions can decrease pH. **Buringh (1970)** reported that Solodization is an intensive leaching which can follow alkalization in older soils. The exchangeable sodium is replaced by $H^+$ ions, and there may be a strong argillation. Leaching clay particles from the A to the B horizon. Consequently, there would be formation of natric horizon with a columnar structure.

All soil properties do not follow a normal distribution, where the value of P of the Shapiro-Wilk Test is less than 0.05 except for CEC (Table 1). Thus, before assuming spatial distribution

**Table 1. Descriptive statistic summary of the selected soil characteristics in current study**

| | MAX | MIN | MEAN | SD | Shapiro-Wilk |
|---|---|---|---|---|---|
| **pH** | 8.33 | 7.09 | 7.61 | 0.38 | **0.001** |
| **EC, $dSm^{-1}$** | 18.15 | 3.39 | 9.43 | 3.79 | < **0.0001** |
| **$CaCO_3$ (%)** | 6.71 | 0.34 | 3.55 | 1.61 | **0.002** |
| **OM (%)** | 0.85 | 0.06 | 0.60 | 0.15 | **0.001** |
| **Available nutrient (mg $kg^{-1}$)** | | | | | |
| **N** | 71.40 | 21.00 | 42.39 | 13.95 | **0.000** |
| **K** | 0.99 | 0.37 | 0.69 | 0.15 | **0.015** |
| **P** | 7.39 | 0.14 | 2.59 | 1.59 | **0.000** |
| **CEC, $cmol_c\ kg^{-1}$** | 74.61 | 22.50 | 47.96 | 10.81 | 0.788 |
| **BD, Mg $m^{-3}$** | 1.75 | 1.08 | 1.31 | 0.10 | < **0.0001** |

of soil properties by ordinary kriging (OK) method, the data was transformed using the Box-Cox method (**Box and Cox, 1964**).

## Correlation Matrix between Soil Properties

Fig. 2 shows the correlation coefficient (r) matrix of soil properties. There were positive, significant correlations between pH with avalaible-N (r = 0.28) and K (r = 0.32), and a negative one between pH and EC (r = -0.24). On the other hand, there were positive significant correlations between EC and $CaCO_3$ (r = 0.23) and between EC and available K (r = 0.51), while there was a negative correlation between EC and available-P (r = -0.39) and between EC and CEC (r = -0.53). There were a positive correlation between $CaCO_3$ and available K (r = 0.38) and a negative one between $CaCO_3$ and OM (r=-0.26) and between $CaCO_3$ and available P (r = -0.37). There was positive correlation between OM and available N (r = 0.55) as well as available P (r = 0.18). Correlation between available N and available P was positive (r = 0.18). There was a negative correlation between available K and available P (r = -0.30) as well as CEC (r = -0.26), and positive one between available P and CEC (r = 0.26). Pairs of other properties have no significant correlations. **Loeppert and Suarez (1996)** observed positive relationship between pH and $CaCO_3$, as well as, between essential plant nutrients.

## Semi-Variogram Parameters and Mapping Soil Properties Using Ordinary Kriging

The spatial distribution pattern of the different soil characteristics was specified using ArcGIS 10.2.1 program using Ordinary Kriging (OK) for ‘’Interpolation mapping’’ to estimate the values of soil properties for un-sampled locations. Based on several criteria such as SDC, ME, RMSE, MSE, RMSSE and ASE, the Semi-variogram was evaluated (Table 2 and Fig. 3). The best fit model of soil EC, available K and BD was the ‘’Stable model’’, where as the ‘’K-Bessel’’ model was the best fit model for pH, OM and CEC, Using the ‘’Exponential model’’ showed the best fit with $CaCO_3$, available N and available P (Table 2 and Fig. 3). The nugget values of all the studied parameters were negligible, varied from 0 to 1.23, except the nugget value of CEC, which was considerable (70.48). However, the sill values varied from 0.01 to 215.44.

**Zhang *et al.* (2007)** reported that large nugget values indicates that the soil indicators are affected by ecological practices over a limited-scale and that selected sampling distance could not clearly capture the spatial dependence. Sill values indicating the difference of the sampled population at large separation distance

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **1- pH** | **1** | **-0.24** | 0.10 | 0.16 | **0.28** | **0.32** | 0.01 | -0.05 | -0.10 |
| 2- EC, dS/m | **-0.24** | **1** | **0.23** | 0.03 | -0.08 | **0.51** | **-0.39** | **-0.53** | 0.00 |
| 3- $CaCO_3$, % | 0.10 | **0.23** | **1** | **-0.26** | -0.07 | **0.38** | **-0.37** | 0.01 | 0.09 |
| 4- OM, % | 0.16 | 0.03 | **-0.26** | **1** | **0.55** | 0.03 | **0.18** | -0.02 | 0.08 |
| 5- Ava. N, $mgkg^{-1}$ | **0.28** | -0.08 | -0.07 | **0.55** | **1** | 0.07 | **0.18** | 0.02 | -0.02 |
| 6- Ava. K, $mgkg^{-1}$ | **0.32** | **0.51** | **0.38** | 0.03 | 0.07 | **1** | **-0.30** | **-0.26** | 0.04 |
| 7- Ava. P, $mgkg^{-1}$ | 0.01 | **-0.39** | **-0.37** | **0.18** | **0.18** | **-0.30** | **1** | **0.26** | -0.17 |
| 8- CEC, $cmol_ckg^{-1}$ | -0.05 | **-0.53** | 0.01 | -0.02 | 0.02 | **-0.26** | **0.26** | **1** | 0.13 |
| 9- BD, $Mgm^{-3}$ | -0.10 | 0.00 | 0.09 | 0.08 | -0.02 | 0.04 | -0.17 | 0.13 | **1** |

Colour scale: 1, 0.8, 0.6, 0.4, 0.2, 0, -0.2, -0.4, -0.6, -0.8, -1

**Fig. 2. Correlation matrix show the values in bold are different from 0 with a significance level alpha = 0.05**

**Table 2. Semi-variogram parameters of the soil properties of the study area**

| | **pH** | **EC** | **$CaCO_3$** | **OM** | **Ava. N** | **Ava. K** | **Ava. P** | **CEC** | **BD** |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | K-Bessel | Stable | Exponential | K-Bessel | Exponential | Stable | Exponenti al | K-Bessel | Stable |
| **Nugget** | 0.00 | 0.00 | 1.23 | 0.00 | 0.00 | 0.00 | 0.80 | 70.48 | 0.00 |
| **Partial sill** | 15.94 | 15.78 | 2.14 | 0.03 | 215.44 | 0.02 | 1.92 | 46.63 | 0.01 |
| **Sill** | 15.94 | 15.78 | 3.37 | 0.03 | 215.44 | 0.02 | 2.72 | 117.11 | 0.01 |
| **Nugget/ Sill** | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 | 0.29 | 0.60 | 0.11 |
| **Major Range** | 4582.15 | 6852.02 | 12581.25 | 2963.95 | 2705.00 | 4213.28 | 4891.50 | 2880.50 | 1582.72 |
| **SDC** | Strong | Strong | Moderate | Strong | Strong | Strong | Moderate | Moderate | Strong |
| **ME** | 0.01 | 0.01 | -0.01 | 0.00 | -0.23 | 0.00 | -0.02 | -0.12 | 0.00 |
| **RMSE** | 3.26 | 3.44 | 1.26 | 0.14 | 11.90 | 0.09 | 1.33 | 9.92 | 0.09 |
| **MSE** | 0.00 | 0.00 | -0.01 | 0.00 | -0.02 | 0.00 | -0.01 | -0.01 | 0.01 |
| **RMSSE** | 0.94 | 0.97 | 0.96 | 1.11 | 1.02 | 0.89 | 1.02 | 1.03 | 1.24 |
| **ASE** | 3.45 | 3.55 | 1.34 | 0.13 | 11.73 | 0.10 | 1.31 | 9.59 | 0.08 |

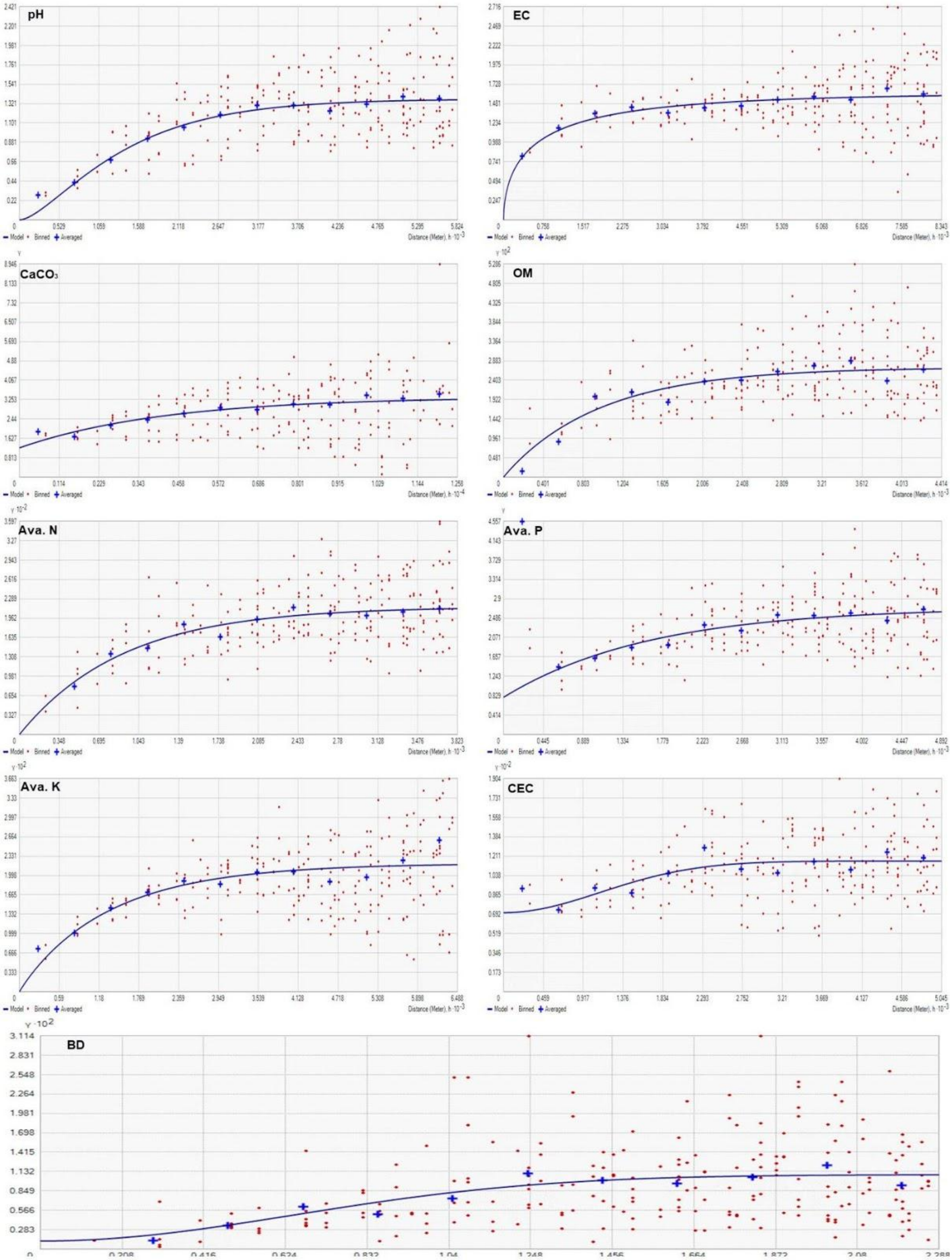


**Fig. 3. Semi-variogram parameters of the soil properties of the study area**

signified that, in case of the data with no trend, sill values are higher in CEC (117.11) and available N (215.49). Variations in nugget and sill values were observed by **Behera *et al.* (2016) and Tesfahunegn *et al.* (2011)**.

Based on **Cambardella *et al.* (1994)** research, nugget to sill ratio values were classified as <0.25 for strong spatial dependence (attributed to intrinsic factors), 0.25 – 0.75 for moderate spatial dependence (attributed to both intrinsic and extrinsic factors) and > 0.75 for weak spatial dependence (attributed to extrinsic factors). Nugget to sill showed ratio values less than 0.25 for all the studied soil properties, except CEC indicating a strong spatial dependence for all studied soil properties, whereas spatial dependence for CEC was moderate. **Behera *et al.* (2018)** mentioned that the strong spatial dependence of soil characteristics is controlled by inherent soil properties, such as mineral composition and texture of the soil whereas extrinsic factors influence moderate and weak spatial dependence of soil properties, such as agricultural practices including tillage and fertilizer application. The range value of semi-variogram varied between 1582.7 for BD to 12581.25 for $CaCO_3$ (Table 2). A large range value indicates that the soil characteristics were affected by natural and human factors over greater distance than soil properties **(López-Granados *et al.*, 2002; Behera *et al.*, 2018)**. The cross-validation technique was used to measure accurate predictions for soil characteristics (Table 2). **Gundogdu and Guney (2007)** reported that the best fit model is that which has mean ME, MSE and ASE values close to zero, and RMSE close to one.

The spatial distribution maps of the different soil characteristics were prepared using ordinary kriging (Fig. 4). The spatial distribution map reveals that 24.76, 14.39, 16.40, 27.36 and 17.09% of the study area had pH value of < 7.17, 7.17 to 7.41, 7.41 to 7.66, 7.66 to 7.89 and > 7.89, respectively. Soil EC showed that 9.15, 28.09, 26.49, 15.46 and 20.81% of the study area had values of < 6.70, 6.71 to 8.17, 8.18 to 9.73, 9.74 to 11.44 and > 11.45 dS $m^{-1}$, respectively. Concerning $CaCO_3$ 22.62, 22.35, 12.57, 27.50 and 17.96% of the study area showed contents of < 2.3, 2.31 to 2.92, 2.93 to 3.76, 3.77 to 4.52 and > 4.53%, respectively. Concerning organic matter, 6.52, 19.98, 21.56, 28.92 and 23.02% of the study area showed organic matter contents of < 0.43, 0.44 to 0.52, 0.53 to 0.61, 0.62 to 69 and > 0.70%, respectively. Regarding available N, there were 30.28, 18.80, 25.74, 23.29 and 15.75% of the study area having values of < 30.28, 30.29 to 37.93, 37.94 to 45.58, 45.59 to 52.64 and > 62.64 mg $kg^{-1}$, respectively. Concerning available P, 14.08, 21.72, 31.70, 21.15 and 11.35% of the study area contained < 1.61, 1.62 to 2.43, 2.44 to 3.31, 3.32 to 4.30 and > 3.41 mg $kg^{-1}$, respectively. For available K 22.87, 22.22, 21.19, 20.95 and 12.77% of the study area showed contents of < 103, 104 to 113, 114 to 124, 125 to 132 and > 132 mg $kg^{-1}$, respectively. Results of CEC showed that 14.50, 28.36, 25.70, 18.57 and 12.88% of the study area had values of < 43.17, 43.18 to 46.81, 46.82 to 50.76, 50.77 to 55.78 and > 55.79 $cmol_c$ $kg^{-1}$, respectively. The BD results showed that 22.14, 41.29, 27.37, 7.28 and 1.92% of the study area were having BD values of < 1.27, 1.28 to 1.32, 1.33 to 1.39, 1.40 to 1.51 and > 1.52 Mg $m^{-3}$, respectively.

**Vasu *et al.* (2017)** mentioned that maps of spatial distribution are able to identify and delineate the problematic zones and represent important tools in site specific management. Spatial distribution of soil characteristics provides a many site information vital for various purposes on environmental forecasting, precision agriculture, and natural resource management (Tan **and Dowling, 1984**).

## Conclusion

As for the above mentioned results, the study confirms that this methodology can be used to clarify spatial variability of soil properties. The results showed that the best fit semivariogram model of $EC_e$, K and BD was stable model, whereas K-Bessel model was the best fit model of pH, OM and CEC, where the exponential model was used the best fit was with $CaCO_3$, N and P. According to the spatial distribution map, five zones were identified, and the study area was classified to < 7.17, 7.17 to 7.41, 7.41 to 7.66, 7.66 to 7.89, and > 7.8 for pH; < 6.70, 6.71 to 8.17, 8.18 to 9.73, 9.74 to 11.4, and > 11.5 dS $m^{-1}$ for EC; < 2.3, 2.31 to 2.92, 2.93 to 3.76, 3.77 to 4.52, and > 4.53% for $CaCO_3$; < 0.43, 0.44 to

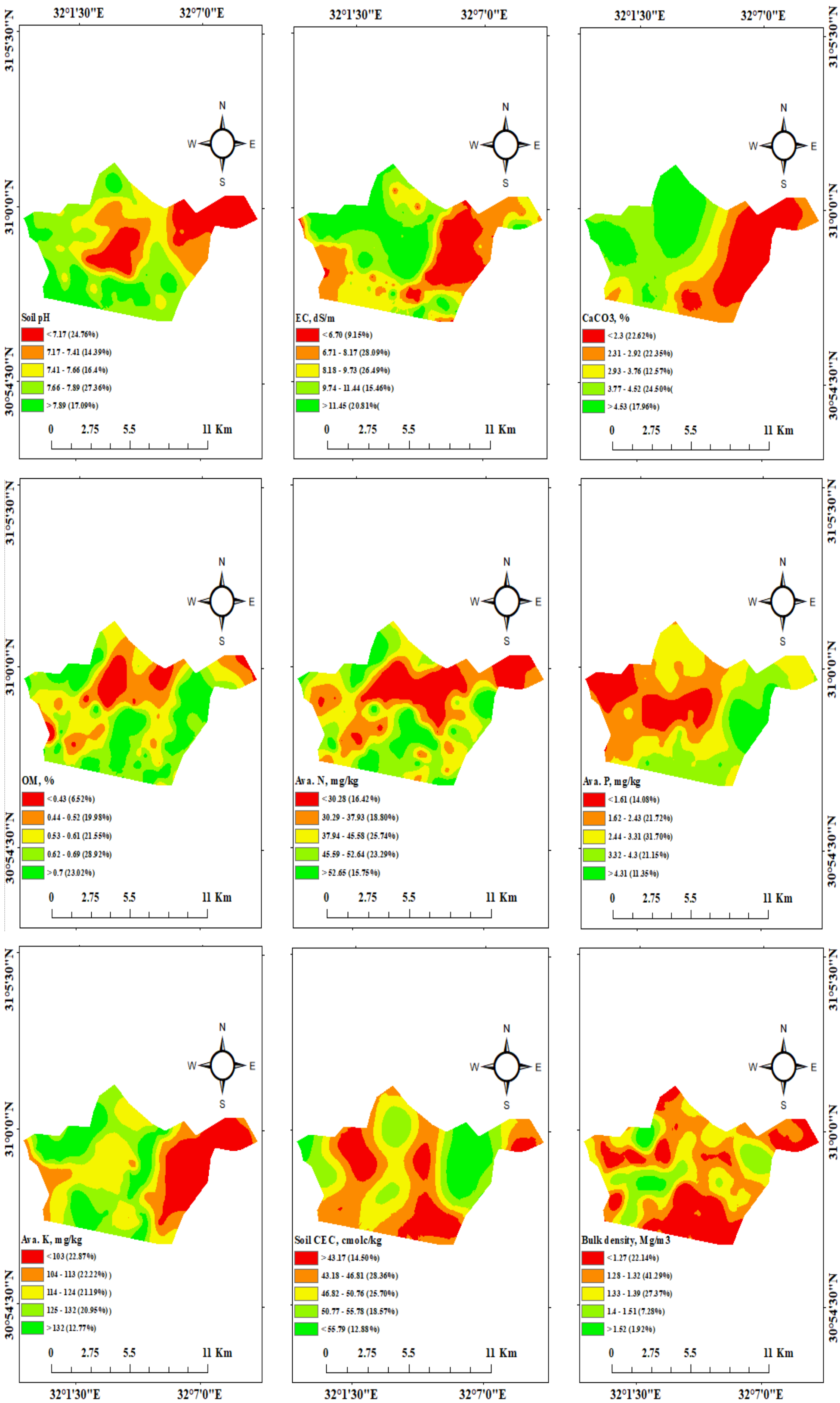


**Fig. 4. Spatial distribution maps of soil characteristic of the study area using kriging method**

0.52, 0.53 to 0.61, 0.62 to 69, and > 0.70% for OM; < 30.3, 30.3 to 37.9, 37.9 to 45.6, 45.6 to 52.6, and > 62.6 mg $kg^{-1}$ for N; < 1.61, 1.62 to 2.43, 2.44 to 3.31, 3.32 to 4.30, and > 3.41 mg $kg^{-1}$ for P; < 103, 104 to 113, 114 to 124, 125 to 132, and > 132 mg $kg^{-1}$ for K, < 43.2, 43.2 to 46.8, 46.8 to 50.8, 50.8 to 55.8, and > 55.8 cmolc $kg^{-1}$ for CEC and < 1.27, 1.28 to 1.32, 1.33 to 1.39, 1.40 to 1.51, and > 1.52 Mg $m^{-3}$ for BD.

## REFERENCES


Abd Elghany, S.H., S.A. Saad, A.A. Arafat and K. Shaban (2019). Effect of different irrigation period and potassium humate on some soil properties and carrot productivity under saline soil conditions. Middle East J. Appl. Sci., 9 (4): 1117-1127.

Ali, A.M. and S.M. Ibrahim (2016). Evaluation of soil fertility using multivariate analysis and GIS in Moghra Oasis, Egypt. Egypt. J Soil Sci., 56 (4): 589-603.

Ali, A.A., K.A. Shaban and E.A. Tantawy (2014). Effect of poly-β-hydroxybutyrate (PHB) and glycogen producing endophytic bacteria on yield, growth and nutrient. Appl. Sci. Reports, 8: 134-142.

Anderson, D. (2010). Solonetzic soils of the Prairie region. PS and C Prairie. Soils and Crops J., 3: 65–72.

Baruah, T. and H. Barthakur (1997). Soil Analysis. Vikas House, New Delhi.

Behera, S.K. and A.K. Shukla (2015). Spatial distribution of surface soil acidity, electrical conductivity, soil organic carbon content and exchangeable potassium, calcium and magnesium in some cropped acid soils of India. Land Degradation and Develop., 26: 71-79.

Behera, S.K., R.K. Mathur, A.K. Shukla, K. Suresh and C. Prakash (2018). Spatial variability of soil properties and delineation of soil management zones of oil palm plantations grown in a hot and humid tropical region of southern India. Catena, 16 (5): 251-259.

Behera, S.K., K. Suresh, B.N. Rao, R.K. Mathur, A.K. Shukla, K. Manorama, K. Ramachandrudu, P. Harinarayana and C. Prakash (2016). Spatial variability of some soil properties varies in oil palm (*Elaeis guineensis* Jacq.) plantations of West coastal area of India. Solid Earth, 7: 979-993.

Bogunovic, I., S. Trevisani, M. Seput, D. Juzbasic and B. Durdevic (2017). Short-range and regional spatial variability of soil chemical properties in an agro-ecosystem in eastern Croatia. Catena, 15 (4): 50-62.

Box, G.E. and D.R. Cox (1964). An analysis of transformations. J. the Royal Statistical Soc., Series B (Methodological), 26: 211-243.

Brevik, E.C., C. Calzolari, B.A. Miller, P. Pereira, C. Kabala, A. Baumgarten and A. Jordán (2016). Soil mapping, classification, and pedologic modeling: History and future directions. Geoderma, 264: 256-274.

Bruulsema, T., G. Malzer, P. Robert, J. Davis and P. Copeland (1996). Spatial relationships of soil nitrogen with corn yield response to applied nitrogen, Proc. 3rd Ed. Int. Conf. Precision Agric.e. Wiley Online Library, 505-512.

Buringh, P. (1970). Introduction to the Study of Soils in Tropical and Subtropical Regions. Buringh. Pudoc. Wageningen. NL, 2nd Ed.

Cambardella, C.A., T.B. Moorman, J. Novak, T. Parkin, D. Karlen, R. Turco and A. Konopka (1994). Field scale variability of soil properties in central Iowa soils. Soil Sci. Soc. Ame. J., 58: 1501-1511.

Cassel, D., E.J. Kamprath and F.W. Simmons (1996). Nitrogen sulfur relationships in corn as affected by landscape attributes and tillage. Agron. J., 88: 133-140.

Davatgar, N., M. Neishabouri and A. Sepaskhah (2012). Delineation of site specific nutrient management zones for a paddy cultivated area based on soil fertility using fuzzy clustering. Geoderma, 173 –174.

Doerge, T. (1999). Defining management zones for precision farming. Crop Insights, 8: 1-5.

FAO (1973). Agriculture Organization of the United Nations (FAO): Calcareous soils: Report of the FAO/UNDP regional seminar on reclamation and management of calcareous soils (FAO Soils Bulletin 21). Cairo, Egypt.

Fraisse, C., K. Sudduth and N. Kitchen (2001). Delineation of site-specific management zones by unsupervised classification of topographic attributes and soil electrical conductivity. Transactions Ame. Soc. Agric. Eng., 44: 155.

Furquim, S.A.C., M.A. Santos, T.T. Vidoca, M. de Almeida Balbino and E.L. Cardoso (2017). Salt-affected soils evolution and fluvial dynamics in the Pantanal wetland, Brazil. Geoderma, 286: 139-152.

Gedroiz, K.K. (1925). Soil absorbing complex and the absorbed soil cations as a basis of genetic soil classification. Nosovka Agric. Exp. Station. 38 (Translation into English: S.A. Waksman).

Goovaerts, P. (1998). Geostatistical tools for characterizing the spatial variability of microbiological and physico-chemical soil properties. Biol. and Fert. Soils, 27: 315-334.

Gundogdu, K.S. and I. Guney (2007). Spatial analyses of groundwater levels using universal kriging. J. Earth System Sci., 116: 49-55.

Hallsworth, E.G. and H.D. Waring (1964). Studies in Pedogenesis in New South Wales. VIII. An alternative hypothesis for the formation of the solodized solonetz of the *Pilliga* district. J. Soil Sci., 15: 158–177.

Heck, R.J. and A.R. Mermut (1992). Genesis of Natriborolls (Solonetzic) in a close lake basin in Saskatchewan, Canada. Soil Sci. Soc. Ame. J., 56: 842–848.

Ibrahim, H.I., A.M. Sallam and K.A. Shaban (2015). Impact of irrigation rates and potassium silicate fertilizer on seed production and quality of Fahl Egyptian clover and soil properties under saline conditions. Ame.-Eurasian J. Agric. Environ. Sci., 15: 1245-1255.

Janzen, W.K. and H.C. Moss (1956). Exchangeable cations in solodized solonetz and solonetz like soils of Saskatchewan. J. Soil Sci., 7: 203–212.

Johnston, K., J. Hoef, K. Krivoruchko and N. Lucas (1996). Using ArcGIS geostatistical analysis. GIS Manual by EARI, New York, 120-187.

Kellog, C.E. (1934). Morphology and genesis of the solonez soils of western South Dakota. Soil Sci., 38 : 483-450.

Khosla, R. and T. Shaver (2001). Zoning in on nitrogen needs. Colorado State Univ. Agron. Newsletter 21: 24-26.

Loeppert, R.H. and D.L. Suarez (1996). Carbonate and gypsum. Methods of Soil Analysis: Part 3 Chem. Methods, 5: 437-474.

López-Granados, F., M. Jurado-Expósito, S. Atenciano, A. García-Ferrer, M.S. de la Orden and L. García-Torres (2002). Spatial variability of agricultural soil parameters in southern Spain. Plant and Soil, 246: 97-105.

Meul, M. and M. Van Meirvenne (2003). Kriging soil texture under different types of nonstationarity. Geoderma, 112: 217-233.

Miller, J.J. and S. Pawluk (1994). Genesis of solonetzic soils as a function of topography and seasonal dynamics. Can. J. Soil Sci., 74: 207–217.

Mohaseb, M.I., M.H. Kenawy and K.A. Shaban (2019). Role of mineral and bio-fertilizers on some soil properties and rice productivity under reclaimed saline soils. Asian Soil Res. J., 1-12.

Mueller, T.G., N. Hartsock, T. Stombaugh, S. Shearer, P. Cornelius and R. Barnhisel (2003). Soil electrical conductivity map variability in limestone soils overlain by loess. Agron. J., 95: 496-507.

Nasef, M., K.A. Shaban, A. El-Hamid and F. Amal (2009). Effect of compost, compost tea and bio-fertilizer application on some chemical soil properties and rice productivity under saline soil condition. J. Agric. Chem. and Biotec., 34: 2609-2623.

Nawar, S., R. Corstanje, G. Halcro, D. Mulla and A.M. Mouazen (2017). Delineation of soil management zones for variable-rate fertilization: A review, Advances in Agron.. Elsevier, 175-245.

Ortega, R. and O. Santibáñez (2007). Agronomic evaluation of three zoning methods based on soil fertility in corn crops (*Zea maize* L.). Computers and Electronics in Agric., 58: 49-59.

Peralta, N., J. Costa, M. Balzarini, M. Franco, M. Cordoba and D. Bullock (2015). Delineation of management zones to improve nitrogen management of wheat. Computers and Electronics in Agric., 110: 103 –113.

Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils. LWW.

Saito, H., S.A. McKenna, D. Zimmerman and T.C. Coburn (2005). Geostatistical interpolation of object counts collected from multiple strip transects: ordinary kriging versus finite domain kriging. Stochastic Environ Res and Risk Assess., 19: 71-85.

Shaban, K., M.A. Attia and A.A. Mahmoud (2010). Response of rice plant grown on newly reclaimed saline soil to a mixture of chelated Fe, Mn and Zn applied by different method and rates. J. Soil Sci. and Agric. Engin., 1: 123-134.

Shukla, A.K., N.K. Sinha, P.K. Tiwari, C. Prakash, S.K. Behera, N.K. Lenka, V.K. Singh, R. Srinivasan, S. Singh, D. Nayak and S. Dharumarajan (2017). Assessment of soil properties and nutrients status in three horticultural land use system of coastal odisha, India. Int. J. Bio-Res. and Stress Manag., 8: 33-40.

Tan, K.H. and P.S. Dowling (1984). Effect of organic matter on CEC due to permanent and variable charges in selected temperate region soils. Geoderma, 32 (2): 89-101.

Tesfahunegn, G.B., L. Tamene and P.L. Vlek (2011). Catchment-scale spatial variability of soil properties and implications on site-specific soil management in Northern Ethiopia. Soil and Tillage Res., 117: 124-139.

Thapa, G. and O.M. Yila (2012). Farmers' land management practices and status of agricultural land in the Jos Plateau, Nigeria. Land Degradation and Develop., 23: 263-277.

Triantafilis, J., I. Odeh and A. McBratney (2001). Five geostatistical models to predict soil salinity from electromagnetic induction data across irrigated cotton. Soil Sci. Soc. Ame. J., 65: 869-878.

Tripathi, R., A. Nayak, M. Shahid, B. Lal, P. Gautam, R. Raja, S. Mohanty, A. Kumar, B. Panda and R. Sahoo (2015). Delineation of soil management zones for a rice cultivated area in eastern India using fuzzy clustering. Catena, 133: 128-136.

Van Reeuwijk, L. (2002). International soil reference and information centre. The Netherlands. Variable charges in selected temperate region soils. Geoderma, 32:89–101.

Vasu, D., S. Singh, N. Sahu, P. Tiwary, P. Chandran, V. Duraisami, V. Ramamurthy, M. Lalitha and B. Kalaiselvi (2017). Assessment of spatial variability of soil properties using geospatial techniques for farm level nutrient management. Soil and Tillage Res., 169: 25-34.

Verity, G. and D. Anderson (1990). Soil erosion effects on soil quality and yield. Canadian J. Soil Sci., 70: 471-484.

Westin, F.C. (1953). Solonetz soils on eastern South Dakota: their properties end genesis. Soil Sci. Soc. Ame. Proc., 17: 287–293

Whittig, L.D. (1959). Characteristics and genesis of a Solodized Solonetz of California. Soil Sci. Soc. Ame. Proc., 23: 469–473.

Xin-Zhong, W., L. Guo-Shun, H. Hong-Chao, W. Zhen-Hai, L. Qing-Hua, L. Xu-Feng, H. Wei-Hong and L. Yan-Tao (2009). Determination of management zones for a tobacco field based on soil fertility. Computers and Electronics in Agric., 65: 168- 175.

Zaidel'man, F.R., M.T. Ustinov and E.Y. Pakhomova (2010). Solods of the Baraba Lowland and the Priobskoe Plateau: their properties and genesis and the methods of their diagnostics. Eurasian Soil Sci., 43: 1069–1082.

Zhang, X.-Y., S. Yue-Yu, X.-D. Zhang, M. Kai and S. Herbert (2007). Spatial variability of nutrient properties in black soil of northeast China. Pedosphere, 17: 19-29.

Zhao, G., X. Mu, Z. Wen, F. Wang and P. Gao (2013). Soil erosion, conservation, and eco-environment changes in the Loess Plateau of China. Land Degradation and Develop., 24: 499-510.

# التبـــاين المكـــانـــى لبعض صفـــات التـــربة فـى ســـهل الحســـينية، محافظة الشـــرقيـــة، مصـــر

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إن الإدارة المستدامة للتربة والفهم الجيد لخصائص التربة يُحدث فرقاً في الحفاظ على مستوى خصوبتها أو تحسينه وتجنب تدهورها، الأمر الذي قد يمثل قضية ذات أهمية عالمياً. لذلك فإن أهداف إجراء هذه الدراسة هي أمكانية دراسة التباين المكاني لخصائص التربة المختارة باستخدام تقنية نظم المعلومات الجغرافية، تم جمع 120 عينة تربة ممثلة لمنطقة الدراسة ومسندة جغرافيا (من صفر إلى 0.60 متر) من سهل الحسينية، محافظة الشرقية، مصر، تضمنت التحليلات درجة الحموضة pH، والتوصيل الكهربائي ECe، كربونات الكالسيوم $CaCO_3$، البوتاسيوم الميسر، النيتروجين الميسر، الفوسفور الميسر، السعة التبادلية الكاتيونية CEC والكثافة الظاهرية BD.تباينت الاعتمادية المكانية spatial dependency لنماذج التوزيع المكاني من معتدلة إلى قوية .أظهرت النتائج أن أفضل نموذج لدالة مخطط التباين semivariogram لكل من درجة التوصيل الكهربي والبوتاسيوم الميسر والكثافة الظاهرية كان نموذج Stable، بينما كان نموذج K-Bessel هو الأفضل لرقم حموضة التربة والمادة العضوية وكذا للسعة التبادلية الكاتيونية، بينما تم استخدام النموذج الأسي exponential مع كربونات الكالسيوم والنيتروجين الميسر والفوسفور الميسر كأفضل نموذج. وفقًا لخريطة التوزيع المكاني، تم تحديد خمس مناطق، حيث تم تصنيف منطقة الدراسة طبقا لدرجة حموضة التربة إلى أقل من 7.17، 7.17 إلى 7.41، 7.41 إلى 7.66، 7.66 إلى 7.89، وأكبر 7.8 وطبقا لدرجة التوصيل الكهربي إلي أقل من 6.70، 6.71 إلى 8.17، 8.18 إلى 9.73، 9.74 إلى 11.4، أكبر من 11.5 ديسيسيمنز/متر وطبقا لكربونات الكالسيوم إلي أقل من 2.3، 2.31 إلى 2.92، 2.93 إلى 3.76، 3.77 إلى 4.52، وأكبر من 4.53%، وطبقا للمادة العضوية في التربة تم تقسيم منطقة الدراسة إلي أقل من 0.43، 0.44 إلى 0.52، 0.53 إلى 0.61، 0.62 إلى 69، وأكبر من 0.70%، أما طبقا للنيتروجين الميسر فتم تقسيمها إلي أقل من 30.3، 30.3 إلى 37.9، 37.9 إلى 45.6، 45.6 إلى 52.6 وأكبر من 62.6 مجم كجم$^{-1}$ وطبقا للفوسفور الميسر تم تقسيمها إلي أقل من 1.61، 1.62 إلى 2.43، 2.44 إلى 3.31، 3.32 إلى 4.30 وأكبر من 3.41 مجم كجم$^{-1}$ وطبقا للبوتاسيوم الميسر كانت أقل من 103، 104 إلى 113، 114 إلى 124، 125 إلى 132 وأكبر من 132 مجم كجم$^{-1}$ وطبقا لسعتها التبادلية الكاتيونية أمكن تقسيمها إلي أقل من 43.2، 43.2 إلى 46.8، 46.8 إلى 50.8، 50.8 إلى 55.8، أكبر من 55.8 سنتيمول كجم$^{-1}$ ووطبقا لكثافتها الظاهرية تم تقسيم منطقة الدراسة إلي أقل من1.27، 1.28 إلى 1.32، 1.33 إلى 1.39، 1.40 إلى 1.51 وأكبر من 1.52 ميجا جرام م$^{-3}$ وبذلك أكدت هذه الدراسة أن هذه المنهجية يمكن استخدامها في دراسة التباين المكاني لخصائص التربة المختلفة.

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