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Evaluation of Spatial Variability of Some Soil Properties and Fertility Status Using Nutrient Index and GIS in Bilqas District, Dakahlia Governorate, Egypt

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ABSTRACT

Tracking changes of spatial variability is important to know soil fertility status. A study was conducted to explore the spatial variability of soil properties using GIS, fertility status using nutrient index and changes of spatial variability comparative with a previous study in Bilqas District, Dakahlia Governorate, Egypt. The studied area covers about 684 km^2. Accordingly, eleven surface soil samples were collected according to the previous study locations using GPS. The obtained results indicated that, the spatial variability maps of soil properties changed from site to other and from time to other. When comparing the spatial variability of soil properties between the current and previous study, it was observed a decreasing in BD, available NP and CEC in the current study. While, there are a increasing in EC, pH, OM, available K, C/N ratio and ESP. In general, the higher values of clay, exchangeable Ca and Mg, OM, TN, C/N ratio, CEC and ESP were observed in the southern parts of the studied area. In contrary, the lower values of sand, silt, exchangeable K and Na, bulk density, EC and pH were monitor in the southern parts, while the lower values of available NPK were observed in northern parts. Soil fertility status evaluation using nutrient index was low according to TN and available N. While, it was medium according to salt index and exchangeable Ca. Additionally, soil fertility status was high according to soil reaction index, OM, available P, available K, CEC, C/N ratio, exchangeable K, Na and Mg.

Keywords: Spatial variability maps, Fertility status evaluation, Change soil properties, Nutrient index, GIS.

INTRODUCTION

Mapping spatial distribution of soil characteristics is the key to effective soil management for sustainable crop yield and helps improvement of agricultural practices, also can support decision makes and resolve with more accurate information needed in developing fertility management programs (El-Sirafy *et al.,* 2011, Behera *et al.* 2016 and Elnaggar *et al*., 2016). Geostatistics provides valuable tools to characterize the spatial distribution of soil properties. Geostatistics enables us to describe spatial patterns by GIS and to predict the values of soil attributes at unsampled locations by a set of statistical tools. 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 (El-Sirafy *et al*., 2011).

Understanding and study of soil characteristics and their distribution are useful for soil management by exist land resources, since soil characteristics vary spatially within soil because of soil-forming factors (Iqbal *et al.* 2005, Valdivia-Cea *et al.,* 2017 and Lelago and Buraka, 2019). Spatial variability of soil properties result from the interaction between the soil forming factors and soil management practices across spatial and temporal scales, and are further modified locally by erosion and deposition processes (Iqbal *et al.,* 2005 and Hu *et al*., 2019).

Spatial variability describe of soil fertility has been difficult until discovered new technologies such as GIS and GPS. GIS is a powerful set of tools for collecting, storing, retrieving, converting and displaying spatial data, which provided important tools for evaluating and mapping of spatial distribution and soil fertility (Burrough and McDonnell, 1998). Soil fertility map depend on spatial distribution of nutrient elements in soil such as total-N, available-PK, Mg and Mn and soil chemical properties (e.g. exchange cations, salinity, OC, and pH (Bagherzadeh *et al.,* 2018). Differences in soil formation factors and soil management lead to spatial variation of soil properties, which is an important determinant of efficiency of farm inputs and yield. Consequently, spatial distribution can provide us important strategies in fertilizer applications and nutrient management and water in agricultural production (Sağlam *et al*., 2011). Spatial distribution and variation of soil properties based on soil characteristics is important for predicting land use changes on soil properties. So, the lack of soil information at a detailed spatial resolution greatly increases the uncertainty of model outputs and becomes an essential limitation for regional land quality appraisals and sustainable land use (Moore *et al.*, 1993, Park and Vlek, 2002, Lian et al., 2009 and Jiang et al., 2017). Despite the importance of soil texture and its relative ease of determination using conventional methods, soil maps are produced at large scales to adequately represent their spatial distribution. Quantitative information on soil surface texture would be extremely useful for modeling,

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planning, and managing the soils (Scull *et al.,* 2005). Results indicated that using GIS tools improved predictions for clay content with soil properties studied and considered to be an accurate and adequate procedure for spatial interpolation and evaluation of soil properties. Also, spatial variability results indicated that soil properties were moderate to strong in the study area (Saleh, 2018). Recent studies show the existence of useful predictive relationships between quantitative environmental variables and soil properties. Accurate and detailed spatial soil information is essential for environmental modeling, risk assessment and decision making (Forkuor *et al.*, 2017).

A nutrient index (NI) of soil properties is distribution estimate percent of soil samples through three classes: high, medium and low of nutrient status (Willy *et al.*, 2019). Nutrient index can be used as a guide and indication on soil fertility status (organic carbon, available phosphorus, available potassium and soil reaction index).

Based on categories chart using pH index, and NI for OC, available PK, soil fertility according to nutrient index was classified as medium (II) to high (III) based on organic carbon. Meanwhile, soil fertility was classified as low (I) according to available phosphorus and potassium (Abah and Petja, 2015). Nutrient index of available nitrogen, phosphorus and potassium was low, low to high and medium to high, respectively. Therefore, variations in soil fertility status were wide (Verma *et al.*, 2005).

This study had the following objectives: 1) identify the spatial distribution of some soil properties, 2) changes of some soil properties from 2010 to now, 3) display the variability of these properties using GIS maps, 4) interrelationships among soil properties and 5) fertility status evaluation of the study area using nutrient index model.

MATERAILS AND METHODS

Field work and soil samples preparation:

This study was carried out at Bilqas District, Dakahlia Governorate, Egypt. The studied area covers about 684 km^2 and located between the coordinates of 31° 10´ 36´´ and 31° 30´ 42´´ N & 31° 14´ 49´´ and 31° 33´ 50´´ E. Eleven soil samples were taken at the soil depth 0-20 cm from the studied area according to the previous study as shown in Fig. (1). Coordinates of soil samples were recorded using the Global Positioning System (GPS). Soil samples were air-dried, crushed to pass through a 2-mm sieve, sieved, and stored to determine their some soil physical and chemical properties. Data obtained from the fieldwork and laboratory analyses were imported to Arc–GIS 10.3. the determined soil properties were carried as pointed out in Table (1).

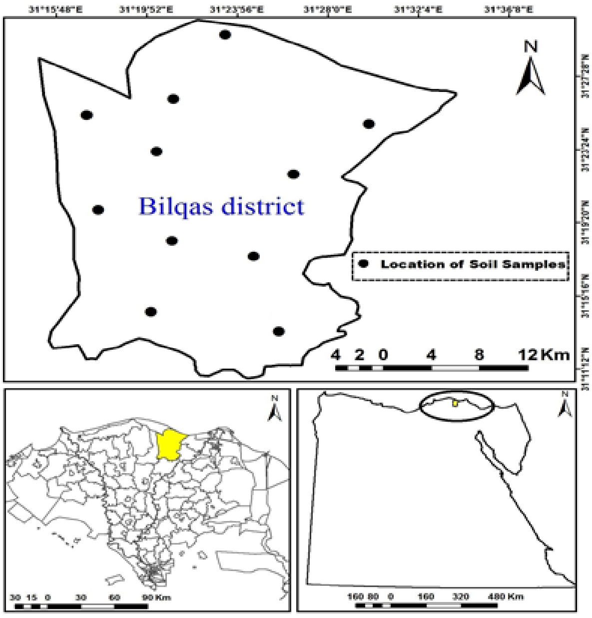

Fig. 1. Location map of the study area and spatial distribution of soil samples.

Physical and chemical analysis

Table 1. Parameters and methods adopted for the laboratory analysis.

Physical and chemical parameters	Methods
Mechanical analysis	Pipette method (Piper,1947)
Bulk density (kgm^{-3})	Dewis and Freitas, (1970).
Soil pH (1:2)	(soil: water) suspension (Schofield and Taylor, 1955)
Electrical conductivity (EC) (dSm^{-1})	Soil paste extract (Hesse, 1971).
Cation exchange capacity (CEC) (cmol kg^{-1})	Sodium and ammonium acetate (Hesse, 1971)
Exchangeable cations (cmol kg^{-1})	1M ammonium acetate of pH 7.0 (Hesse, 1971)
Available nitrogen (mg kg^{-1})	Kjeldahl (Hesse,1971)
Available phosphorus (mg kg^{-1})	Olsen and Sommers, (1982).
Available potassium (mg kg^{-1})	Flame photometer (Hesse, 1971).
Total nitrogen (TN) (%)	TN = 0.026 + 0.067*OC (Rashidi and Seilsepour, 2009).
Organic matter (OM) (%)	Walkley and Black (Hesse, 1971).

Soil nutrient index:

In order to analyze and evaluate soil fertility status, different indices like soil reaction index (pH), and nutrient index with respect to EC, organic matter, available NPK, TN, C/N ratio, exchangeable cations and CEC were calculated based on the classification of critical fertility levels as shown Table (2) according to Verma *et al.*, (2005) , Ravikumar and Somashekar, (2013), and Enang *et al.*, (2016). The rating charts were used according to rate the soil analysis results and nutrient index respectively. Interpretation was done as value given and shown on the Table (3). The nutrient index for soil samples were calculated using Equation 1 (Ramamurthy and Bajaj, 1969 and Ravikumar and Somashekar, 2013):

$$\textbf{Nutrient Index (NI)} = (NL \times 1 + NM \times 2 + NH \times 3) / NT \quad \text{…… Equation 1}$$

Where, **NL is number of samples rated low, NM is number of samples rated medium, NH is number of samples rated high and NT is total number of samples.**

Table 2. Classification of critical fertility levels in soils for the used soil properties

Parameters		Unit	Critical fertility level		
			Low	Medium	High
Soil pH [1]			< 6	6 - 8	> 8
EC [3]		(dSm^{-1})	< 4	4 – 8	> 8
Organic matter [1]		(%)	< 0.86	0.86 - 1.29	> 1.29
Available N [2]		(mg kg^{-1})	< 108	108 - 217	> 217
Available P [2]		(mg kg^{-1})	< 5	5 - 9	> 9
Available K [2]		(mg kg^{-1})	< 45	45 - 112	> 112
Total (N) [3]		(%)	< 0.125	0.125 - 0.225	> 0.225
C/N ratio [3]			> 14 = poor	10 - 14 = medium	< 10 = good
Exchangeable cations [3]	K^+	(cmol kg^{-1})	> 0.3	0.3 – 0.6	> 0.6
	Na^+		> 0.3	0.3 – 0.7	> 0.7
	Ca^{2+}		> 5	5 -10	> 10
	Mg^{2+}		> 1.5	1.5 - 3	> 3
CEC [3]		(cmol kg^{-1})	> 12	12 - 25	> 25

1 (Ravikumar and Somashekar, 2013), 2(Verma *et al.* 2005), 3 (Enang *et al.*, 2016).

Table 3. Rating chart of nutrient index (Ramamurthy and Bajaj, 1969 and Ravikumar and Somashekar, 2013)

Nutrient index	Categories	Value
I	Low (L)	< 1.67
II	Medium (M)	1.67 - 2.33
III	High (M)	> 2.33

Statistical analysis

Descriptive statistics for the ranges, averages, standard deviations (STDEV), coefficient of variation (C.V) and difference % of soil properties were performed using Microsoft Excel Software (Version 2010, Microsoft Corporation, USA). Correlation coefficients between soil properties were calculated using SPSS classical statistics.

RESULTS AND DISCUSSION

Soil texture

Descriptive statistics of particle size distribution values shown in Table (4). This revealed that soil textures in the studied area were varied from sandy to clay loam. The clay, silt and sand percentages ranged from 0.00 to 43.60 % with an average of 28.15 %, 0.00 to 29.07 % with an average of 13.08 %, and 35.81 to 100.00 % with an average of 58.77 %, respectively. The spatial distribution of soil clay, silt and sand are illustrated in Fig. (2). This figure revealed obvious variations in particle size distribution values within soil samples represented the studied area. The higher values of clay were observed in the southern parts of the studied area. On the contrary, the higher values of sand were watched near the northern parts of the studied area, which may due to near location of studied area from the Mediterranean Sea. While, the higher values of silt was founded in the middle of study area.

Table 4. Descriptive statistics for soil selected physiochemical properties.

Soil properties		Min.	Max.	Average	STDEV[1]	CV[2] %
Particle size distribution[3]	Clay %	0.00	43.60	28.15	14.62	51.92
	Silt %	0.00	29.07	13.08	12.29	93.93
	Sand %	35.81	100.00	58.77	23.08	39.27
Soil texture		Sandy to clay loam				
Exchangeable cations (cmol kg^{-1})	K^+	0.12	2.00	0.98	0.62	62.87
	Na^+	0.12	10.15	3.33	3.66	110.06
	Ca^{2+}	1.08	21.18	10.85	6.56	60.46
	Mg^{2+}	1.95	13.17	8.84	3.91	44.27

[1]Standard Deviation [2]Coefficient of Variation [3](after Omar, 2010).

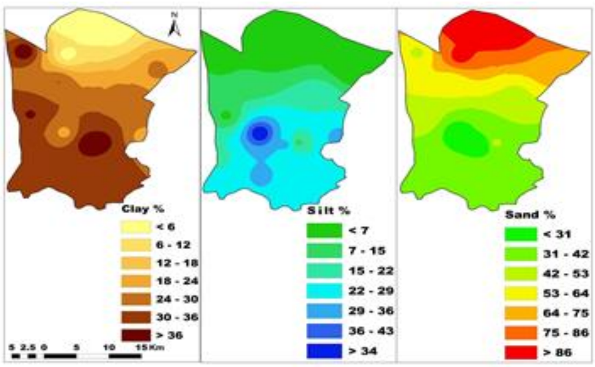

Fig .2. Spatial variability of clay, silt and sand in the soils of the studied area.

Exchangeable cations

Data in Table (4) show descriptive statistics of exchangeable cations (cmol kg^{-1}) of the studied area. Exchangeable K ranged between 0.12 and 2.00 cmol kg^{-1} (with an average value of 0.98 cmolkg^{-1}). The average of exchangeable Na was 3.33 cmol kg^{-1}, where it varied from 0.12 to 10.15 cmol kg^{-1}. In addition, exchangeable Ca varied between 1.08 and 21.18 cmol kg^{-1} (recorded average value of 10.85 cmol kg^{-1}), Meanwhile, exchangeable Mg ranged between 1.95 and 13.17 cmol kg^{-1} (with mean value of 8.84 cmolkg^{-1}). Exchangeable cations (K, Na, Ca and Mg) of the studied area were ranged from low to high except exchangeable Mg was ranged from medium to high according to Enang *et al.*, (2016). Fig. (3) illustrates the spatial distribution and variations of exchangeable cations (Ca, K, Mg and Na). In general, higher values of exchangeable Ca and Mg were observed in the southern parts of the studied area. On the contrary, the higher values of exchangeable K and Na were found near the north western of the studied area.

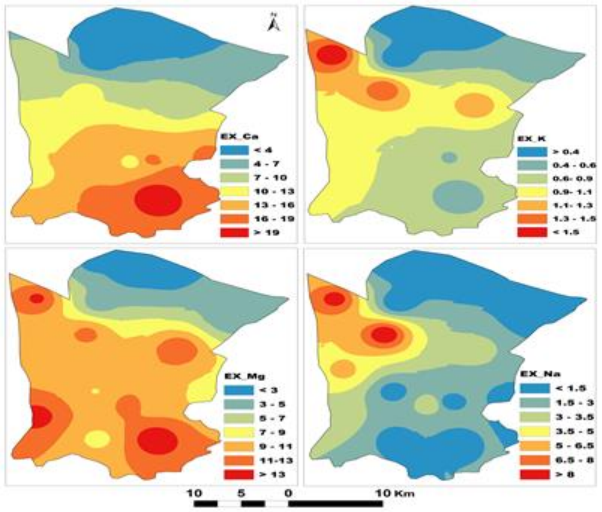

Fig. 3. Spatial variability of exchangeable Ca, K, Mg and Na in the soils of the studied area.

Soil properties selected for comparative

Data in Tables (5 and 6) show descriptive statistics of some soil properties selected and percentage change for comparative between both of current and previous study such as bulk density (gcm^{-3}**)**, soil EC (dSm^{-1}), pH, OM (%), available NPK (mg kg^{-1}), TN (%), C/N ratio, CEC (cmolkg^{-1}) and ESP (%).

Bulk density (BD)

Data in Table (5) show that there are variations in bulk density values between the present and past study, where its average values were 1.16 and 1.43 kgm^{-3} with variations low of 15.12 and 11.57 %), respectively. All previous data indicate to decrease of soil bulk density where change and percentage change between the two studies were -0.27 and -19.34 %, respectively. Fig. (4) illustrates the spatial distribution and variations of bulk density and difference % between the two studies. As shown in the figure, the higher values of bulk density were observed in the northern parts of the studied area. On the contrary, the lower values were watched in the southern parts of the studied area in both studies. These variables in results due to increase in the soil content of OM content and clay which have clear effects on texture in the southern parts (fine texture) compared with the northern parts (coarse texture) of the studied area. Relationships between soil bulk density with the soil content of OM, clay and sand were shown in Fig. (5). These figures showed that bulk density of soil depends on its organic matter content as well as the particles size distribution (Chaudhari *et al.*, 2013; Ahad *et al.*, 2015 Elnaggar, 2017, Olorunfemi *et al.*, 2018 and El-Seedy and Saeed, 2019).

Table 5. Descriptive statistics for soil selected physiochemical properties.

Soil properties		Current study			Previous study[1]		
		Min.	**Max.**	**Average ± STDEV (CV %)**	**Min.**	**Max.**	**Average ± STDEV (CV %)**
Bulk density (kgm^{-3})		0.99	1.54	1.16 ± 0.18 (15.12)	1.31	1.75	1.43 ± 0.17 (11.57)
EC (dSm^{-1})		2.02	17.50	7.29 ± 6.09 (83.44)	1.57	12.50	4.49 ± 3.26 (72.67)
pH		8.30	9.02	8.49 ± 0.22 (2.61)	7.50	7.90	7.73 ± 0.14 (1.81)
Organic matter %		0.37	2.43	1.54 ± 0.62 (40.42)	0.32	1.86	1.01 ± 0.60 (59.12)
Available NPK (mg kg^{-1})	N	20.86	66.41	39.88 ± 13.01 (32.61)	32.00	88.00	45.39 ± 16.70 (36.79)
	P	5.82	22.25	11.45 ±6.16 (53.78)	7.33	19.00	14.45 ±3.72 (25.73)
	K	54.33	901.26	428.09 ± 249.69 (58.33)	40.00	561.00	329.21 ± 151.80 (46.11)
TN %		0.03	0.12	0.08 ± 0.03 (36.32)	0.04	0.12	0.08 ± 0.03 (39.10)
C/N ratio		5.29	11.70	9.94 ± 1.87 (18.80)	5.72	11.69	8.95 ± 2.41 (26.89)
CEC (cmolkg^{-1})		3.41	37.90	25.01 ± 12.54 (50.15)	2.33	42.86	26.46 ± 13.66 (51.62)
ESP %		2.37	26.78	10.81 ± 9.27 (85.71)	1.04	10.02	5.23 ± 3.02 (57.69)

[1](after Omar, 2010).

Table 6. Descriptive statistics of change and percentage change between soil properties values for the two studies.

Soil properties		**Change**	**Min.**	**Max.**	**Average**	**STDEV**	**CV**
Bulk density		Change	-0.38	-0.20	-0.27	0.06	-21.67
		Percentage change	-27.74	-12.17	-19.34	4.45	-23.03
EC		Change	-3.94	15.90	2.81	5.86	208.81
		Percentage change	-66.15	992.68	140.03	303.86	217.00
pH		Change	0.40	1.42	0.76	0.26	34.59
		Percentage change	5.06	18.68	9.81	3.50	35.70
Organic matter		Change	-0.36	2.10	0.53	0.71	133.41
		Percentage change	-20.22	625.37	114.66	192.28	167.70
Available NPK	N	Change	-47.78	19.80	-5.51	17.77	-322.57
		Percentage change	-54.30	61.88	-7.24	32.60	-450.29
	P	Change	-10.42	7.25	-3.00	5.52	-183.93
		Percentage change	-54.84	48.33	-20.90	34.73	-166.13
	K	Change	-145.64	564.26	98.87	242.27	245.03
		Percentage change	-29.84	290.58	46.80	99.04	211.61
TN		Change	-0.04	0.08	0.01	0.04	660.34
		Percentage change	-54.46	179.67	19.42	66.30	341.43
C/N ratio		Change	-1.43	5.84	0.99	2.36	238.47
		Percentage change	-12.31	99.71	17.26	37.12	215.02
CEC		Change	-15.13	16.53	-1.45	8.57	-591.96
		Percentage change	-61.68	146.93	6.64	54.18	816.16
ESP		Change	-3.40	16.93	5.58	7.54	135.07
		Percentage change	-55.21	392.16	124.83	150.58	120.63

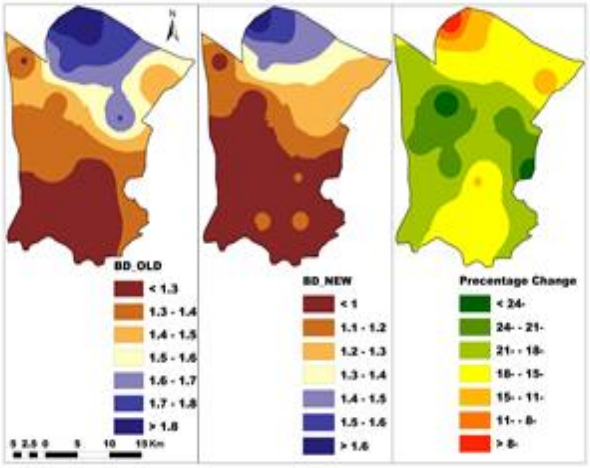

Fig. 4.Spatial variability of bulk density and percentage change between the two studies.

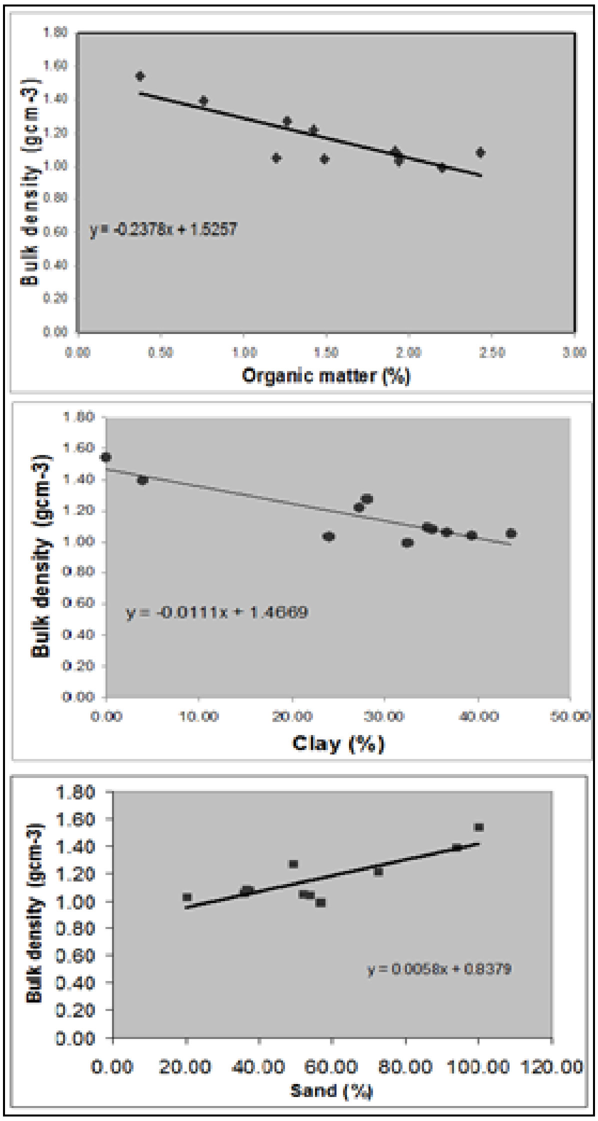

Fig. 5. Linear relationships between the soil content of organic matter, clay and sand with bulk density of current study in the soils of the studied areas.

Electrical conductivity (EC) and soil pH

Average values of EC found in both the current and previous study on the studied area varied between 7.29 and 4.49 dSm^{-1} with coefficient variation of 83.44 and 72.67 %, respectively. The spatial distribution for soil EC and pH values in the studied soils is illustrated in Fig. (6). According to EC values concluded that the soil samples represented the soil of the studied area varied from non-saline to very strongly saline (Enang *et al.*, 2016). The higher values of EC were observed in the northern parts in both studies, which are nearest of the Mediterranean Sea. Salinization is a major factor contributes in decreasing crop yield and soil degradation (Prapagar *et al.*, 2015 and El-Seedy and Saeed, 2019).

In addition, the average values of soil pH in the current and previous studies were 8.49 and 7.73 with CV of 2.61and 1.81 %, respectively. Also, averages of EC and pH changes and percentages change between the two studies were (2.81, 140.03%) and (0.76, 9.81%), respectively. The increase in salinity and alkalinity degree may be due to the increase in droughts and temperatures in the delta region during the past decades according to Abdelaal, (2018).

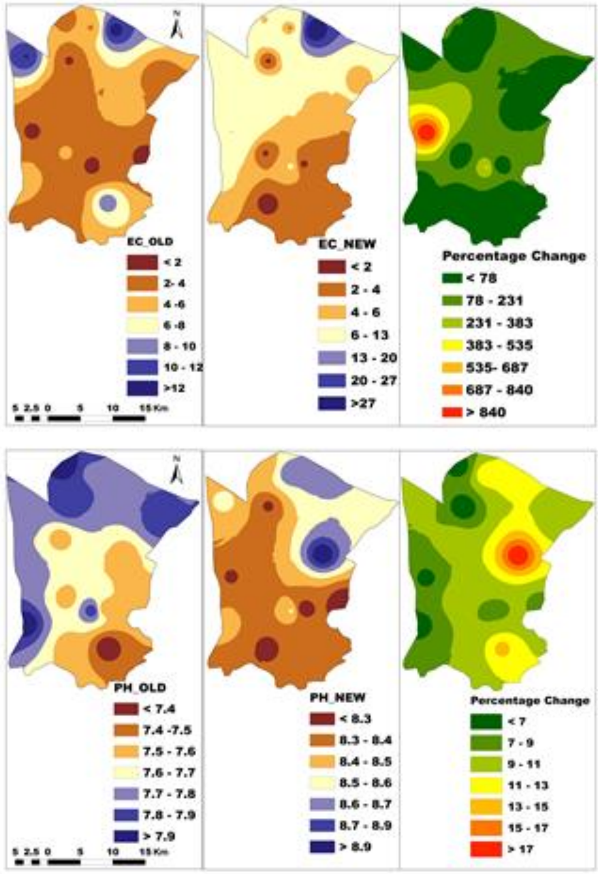

Fig. 6. Spatial variability of EC, pH and percentage change between the two studies.

Organic matter (OM)

According to Ravikumar and Somashekar, (2013) organic matter content in present study was ranged from low to high (0.37 to 2.43 %). Average content of organic matter in present study (1.54 %) was higher than previous study (1.01 %). In opposite, variation coefficient in present study (40.42 %) was lowest than previous study (59.12 %).

The lower contents of OM were found in coarse textured soils located in the northern parts in both studies, while the higher contents were found located in the fine textured soils in the middle parts of previous study and in the middle and southern parts of current study as illustrated in Figs. (7 and 8) (Plante *et al.*, 2006, Hartati and Sudarmadji, 2016, Elnaggar, 2017 and El-Seedy and Saeed, 2019). Average of OM change and percentage change between the two studies were 0.53 and 114.66 %, respectively as shown in Table (6). The increase of organic matter in the current study compared with the previous study may be due to increase farmer's awareness with role of organic matter in the newly reclaimed areas. Consequently therefore, addition of organic fertilizers by farmers for soils characteristics improvement.

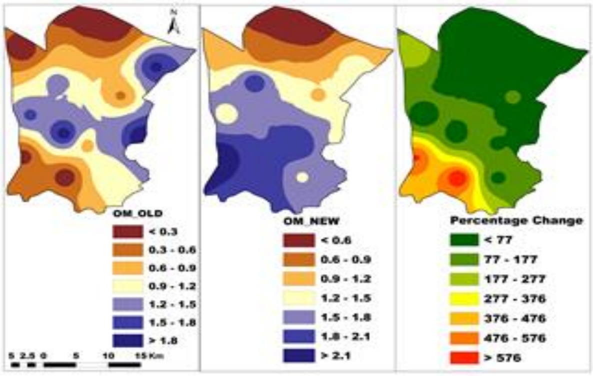

Fig .7. Spatial variability of OM % and percentage change between the two studies.

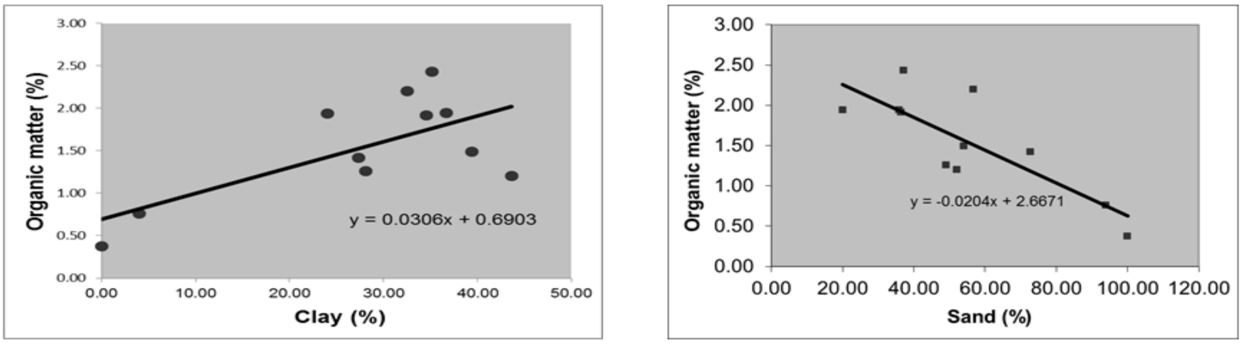

Fig .8. Linear relationships between clay and sand with organic matter of current study in the soils of the studied areas.

Available NPK

Available N was ranged from low to high (20.86 to 66.41 mg kg^{-1}) as found from the current study, while available P and K were ranged from medium to high (5.82 to 22.25 and 54.33 to 901.26 mg kg^{-1}), respectively (Verma *et al.* 2005). In general, there are wide variations in the soil content of available NPK values between the two studies, where the averages of available NPK contents were 39.88, 11.45 and 428.09 mg kg^{-1} at current study, respectively, while were 45.39, 14.45 and 329.21 mg kg^{-1} at previous study, respectively. These data indicate to decrease in the soil contents of available N and P in the current study where averages values of change and percentage change between the two studies were (-5.51 and -7.24 %) and (-3.00 and -20.90), respectively. In opposite, the content of available K has an increase averages values which were 98.87 and 46.80 %. Fig. (9), illustrates the spatial distribution and variations of available NPK and difference % between the two studies. As shown in the figure, the lower content of available NPK observed in the northern parts of the studied area, which might be because of sandy texture in this part from area. In general, the higher values were watched close to the middle parts of the studied area in both studied. Also, there was no obvious pattern in the spatial distribution of available NPK within the studied soils. Average of available NPK change and percentage change between the two studies were (-5.51 and -7.24%), (-3.00 and -20.90 %) and (98.87 and 46.80 %), respectively as shown in Table (6).

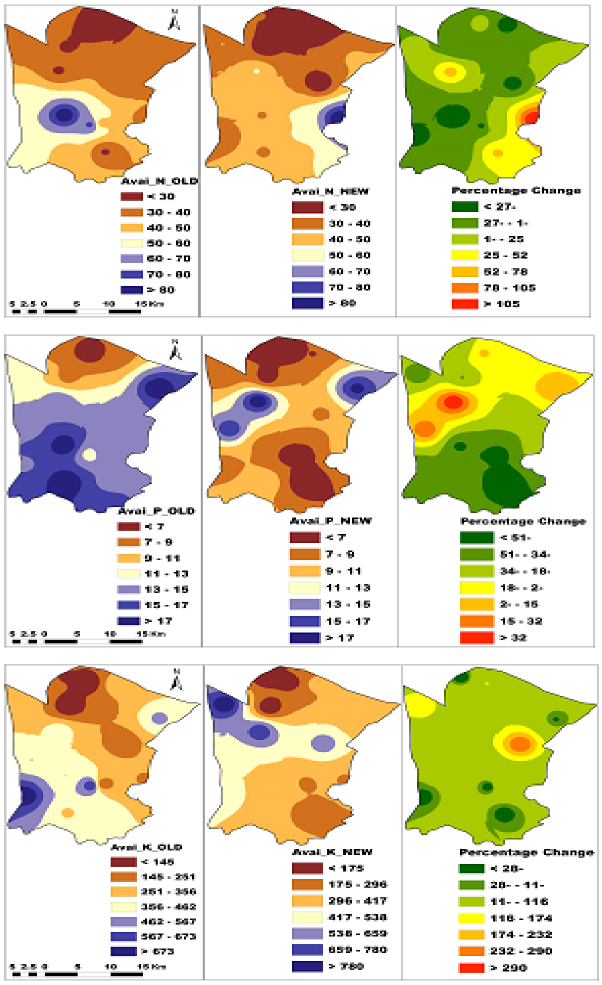

Fig .9. Spatial variability of Available NPK and percentage change between the two studies.

Total nitrogen (TN) and C/N ratio

Total nitrogen content varied from low to medium (0.03 to 0.12 %), while C/N ratio values varied from medium to good (11.70 to 5.29) with the current study according to Enang *et al.*, (2016). The average of total nitrogen found the current and previous studies in the studied area not changed (0.08 %). While, variation coefficient values were 36.32 and 39.10 %, respectively. Average values of C/N ratio in the current and previous studies in the studied area were 9.94 and 8.95, respectively.

While, its CV values were 18.80 and 26.89 %, respectively. The spatial distribution of TN and C/N ratio values in the studied soils is illustrated in Fig. (10). The higher values of TN and C/N ratio were observed in the southern parts in the current study, but in the previous study observed in the middle parts. Average of TN and C/N ratio change and percentage change between the two studies were 0.01and -19.42 %) and (0.99 and 17.26 %), respectively as shown in Table (6). Highly significant correlations were found between soil organic matter (SOM) content with total N % and C/N ratio (r = 0.98 and 1.00, respectively) as shown in Table (7) and Fig. (11).

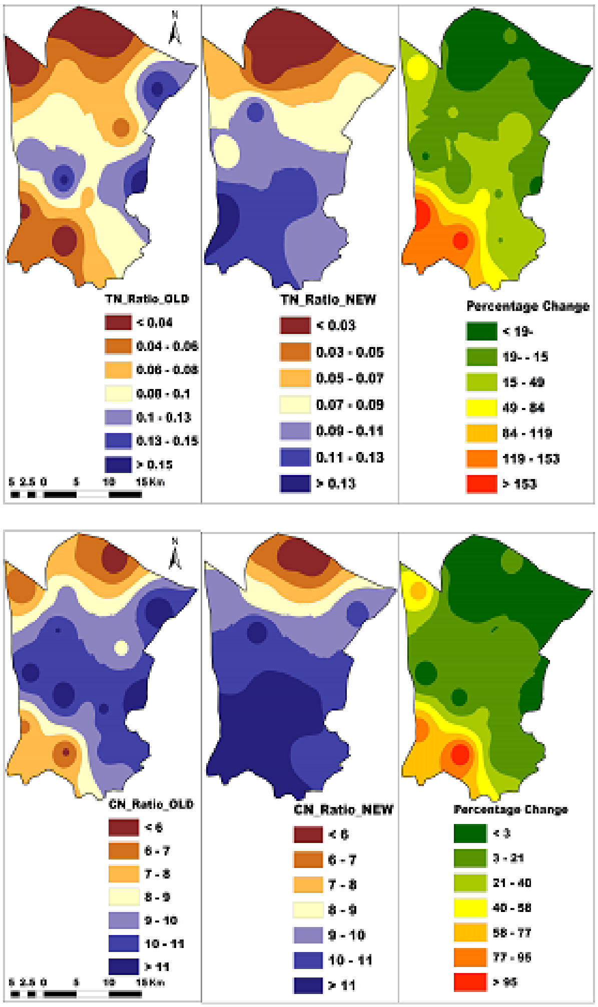

Fig .10. Spatial variability of TN, C/N ratio and percentage change between the two studies.

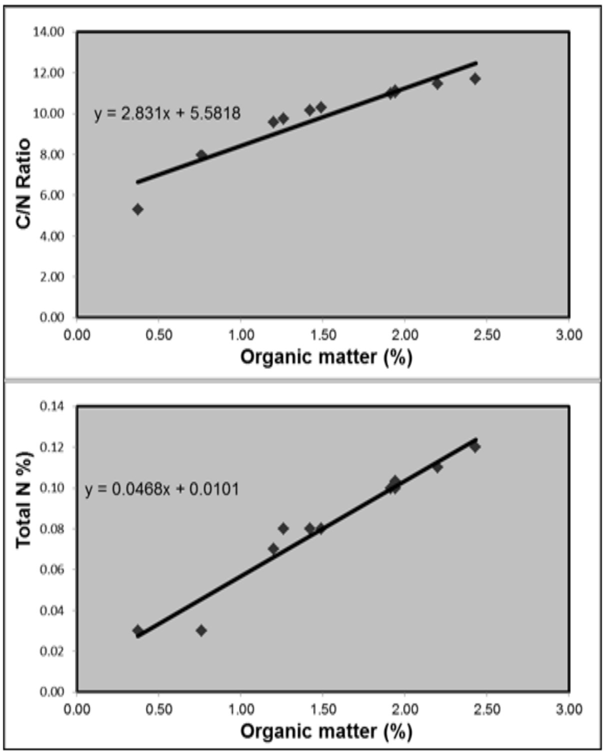

Fig .11. Linear relationships between C/N ratio and TN % with organic matter of current study in the soils of the studied areas.

Cation exchangeable capacity (CEC) and exchangeable sodium percentage (ESP)

Cation exchangeable capacity values varied from low to high (3.41to 37.90 cmolkg^{-1}) according to Enang *et al.* (2016). Also, according to Motsara and Roy (2008) exchangeable sodium percentage values varied from low to high (2.37 to 26.78 %) with the current study. Average values of CEC found in the current and previous studies in the studied area were 25.01 and 26.46 cmolkg^{-1}, respectively. While, its CV values were 50.15 and 51.62 %, respectively. Additionally, ESP average values of the current and previous studies in the studied area were 10.81 and 5.23 %, respectively. While, its variation coefficient values were 85.71 and 57.69 %, respectively. The spatial distribution of CEC and ESP values in the studied soils is illustrated in Fig. (12). In general, the lower values of CEC and ESP were observed in the northern parts of the current study. Averages of CEC and ESP change and percentage change between the two studies were (-1.45 and 6.64 %) and (5.58 and 124.83 %), respectively as shown in Table (6).

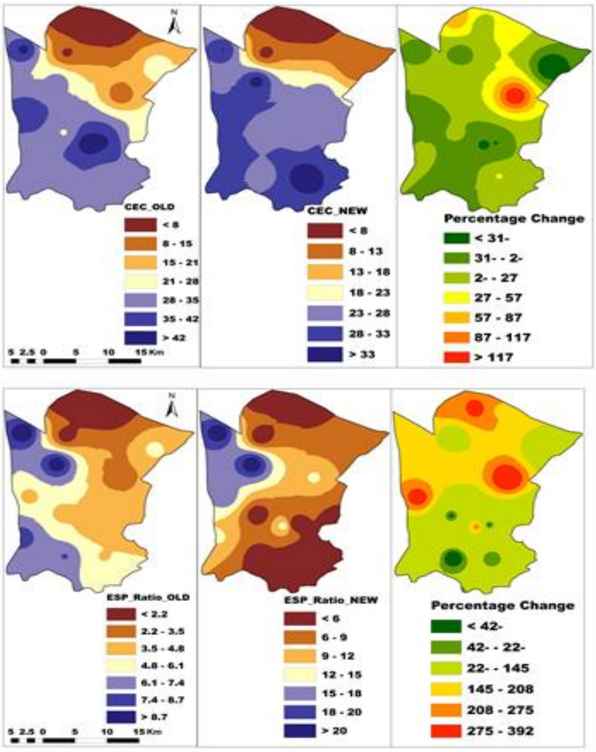

Fig .12. Spatial variability of CEC, ESP and percentage change between the two studies.

Interrelationships between soil properties

Data in Table (7) and Fig. (13) show highly significant and significant correlations between some soil properties of the soils of the studied area. Highly positive and significant correlations were observed between clay content and CEC and exchangeable Na (r = 0.77). While, there were a significantly correlations with ESP and exchangeable Mg (r = 0.61 and 0.67, respectively). Silt content was highly positive and significant correlations with TN, C/N ratio and exchangeable Ca (r = 0.76, 0.74 and 0.91, respectively). While, was correlated significant with OM (r = 0.73). Also, a significant correlation was found between EC and ESP (r = 0.67). OM content was highly significant correlations with TN, C/N ratio and exchangeable Ca (r = 0.98, 1.00 and 0.80, respectively). While, was correlated significant with available P (r = 0.61). Also, CEC was highly positive and significant correlated with exchangeable K, Na and Mg (r = 0.75, 0.83 and 0.76, respectively). While, was correlated significant with available N, available K and exchangeable Ca (r = 0.64, 0.69 and 0.62, respectively). Also, significant correlation was observed between available P with TN, C/N ratio (r = 0.61 and 0.62, respectively). Available K was correlated highly positive and significant with ESP, exchangeable K, Na and Mg (r = 0.82, 0.96, 0.88 and 0.75, respectively). Additionally, C/N ratio was highly significant correlations with exchangeable Ca (r = 0.80).

Similarly, highly significant correlation was found between ESP and exchangeable Na (r = 0.90). While exchangeable K was highly positive and significant correlated with exchangeable Na and Mg (r = 0.87 and 0.84, respectively).

Exchangeable Na was highly positive and significant correlated with exchangeable Mg (r = 0.79). There are significant correlation was observed between ESP and exchangeable K (r = 0.73).

On the other hand, negative and highly significant correlations were found between sand content with silt content and exchangeable Ca (r = 0.92 and 0.88, respectively). Also, negative correlation was obtained between BD with CEC (r = .77). There are significant and negative correlation between sand content with OM, TN and C/N ratio (r = 0.63, 0.65 and 0.64, respectively). Similarly, the BD had a significant and negative correlated with OM, available N, available K, C/N ratio, exchangeable K, exchangeable Na and exchangeable Ca (r = 0.68, 0.62, 0.62, 0.69, 0.63, 0.64, and 0.64, respectively).

Nutrient Index (NI) of soil properties

Data in Table (8) and Fig. (14) show the nutrient index and categories of some soil parameters of the studied area. Based on classification of critical fertility levels and rating chart as given in Tables (2 and 3), categories of soil fertility status in the study area were classified into three classes (low, medium and high) according to nutrient index values. The nutrient index (NI) varied from parameter to other; this indicate to various soil fertility status due to this parameters.

The soil fertility status was low according to available N (1.00) and total nitrogen (1.09). While, nutrient index for salt index (2.09) and exchangeable Ca (2.27) were medium; these data indicate to that the soil fertility status was medium according to EC and exchangeable Ca. Additionally, soil fertility status was high according to nutrient index of these parameters as following: soil reaction index (3.00), organic matter (2.45), available P (2.45), available K (2.913), CEC (2.45), C/N ratio (2.36), exchangeable K (2.64), exchangeable Na (2.45) and exchangeable Mg (2.91), (Verma *et al.*, 2005; Abah and Petja, 2015; Willy *et al.*, 2019 and El-Seedy, 2019).

Table 7. Correlation coefficients between soil properties in the soils of the studied area.

Soil properties	Clay	Sand	Silt	EC	pH	BD	OM	CEC	Avai_N	Avai_P	Avai_K	TN	C/N Ratio	ESP	Ex_K	Ex_Na	Ex_Ca
Clay	1																
Sand	-0.42	1															
Silt	0.27	-0.92**	1														
EC	0.24	0.49	-0.59	1													
pH	-0.26	0.09	-0.20	0.31	1												
BD	-0.55	0.47	-0.47	-0.16	0.26	1											
OM	0.37	-0.63*	0.73*	-0.28	-0.25	-0.68*	1										
CEC	0.77**	-0.38	0.42	0.10	-0.29	-0.77**	0.56	1									
Avai_N	0.54	-0.30	0.23	0.09	-0.41	-0.62*	0.54	0.64*	1								
Avai_P	0.23	-0.08	0.16	0.25	0.13	-0.51	0.61*	0.40	0.36	1							
Avai_K	0.57	-0.18	0.16	0.43	0.301	-0.62*	0.29	0.69*	0.12	0.56	1						
TN	0.34	-0.65*	0.76**	-0.33	-0.15	-0.60	0.98**	0.56	0.50	0.61*	0.30	1					
C/N Ratio	0.35	-0.64*	0.74**	-0.29	-0.23	-0.69*	1.00**	0.56	0.51	0.62*	0.30	0.98**	1				
ESP	0.61*	0.19	-0.22	0.67*	0.17	-0.40	0.16	0.60	0.25	0.54	0.82**	0.16	0.14	1			
Ex_K	0.60	-0.36	0.36	0.26	0.25	-0.63*	0.40	0.75**	0.12	0.43	0.96**	0.43	0.41	0.73*	1		
Ex_Na	0.77**	-0.18	0.17	0.39	-0.04	-0.64*	0.40	0.83**	0.39	0.54	0.88**	0.40	0.38	0.90**	0.87**	1	
Ex_Ca	0.46	-0.88**	0.91**	-0.47	-0.34	-0.64*	0.80**	0.62*	0.58	0.25	0.173	0.80**	0.80**	-0.12	0.34	0.26	1
Ex_Mg	0.67*	-0.42	0.42	-0.03	0.04	-0.37	0.24	0.76**	0.14	0.17	0.75**	0.32	0.24	0.57	0.84**	0.79**	0.40

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

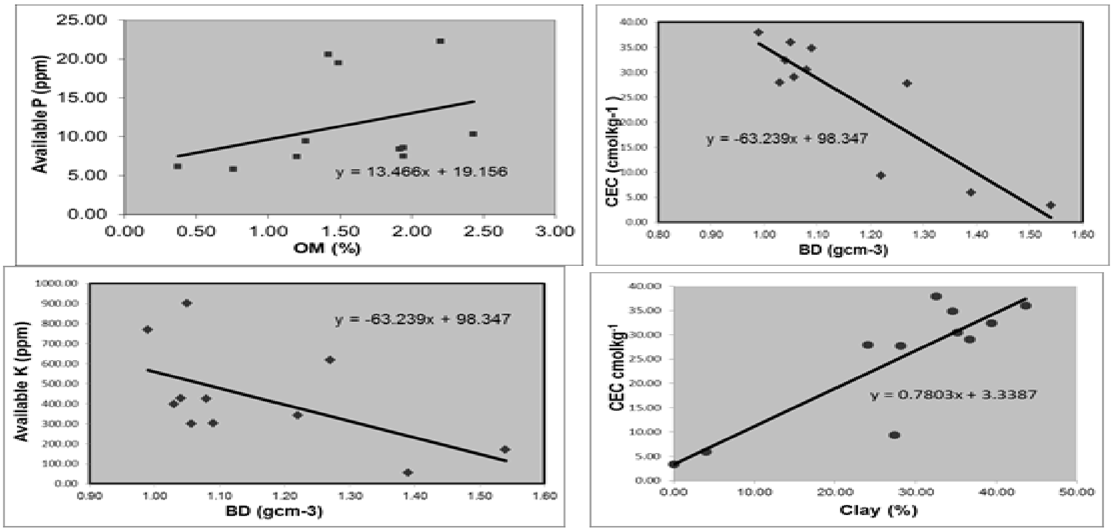

Fig .13. Linear relationships between some soil properties in the soils of the studied area.

Table 8. Nutrient index of some soil parameters in the studied area.

Parameters		Number of samples Low	Medium	High	Nutrient index values	Categories	Nutrient Index
Soil pH		0	0	11	3.00	High	III
Electrical conductivity		3	4	4	2.09	Medium	II
Organic matter		2	2	7	2.45	High	III
Available	N	11	0	0	1.00	Low	I
	P	0	6	5	2.45	High	III
	K	0	1	10	2.91	High	III
Cation exchangeable capacity		3	0	8	2.45	High	III
Total nitrogen		10	1	0	1.09	Low	I
C/N ratio		0	7	4	2.36	High	III
Exchangeable cations	K	2	0	9	2.64	High	III
	Na	2	2	7	2.45	High	III
	Ca	3	2	6	2.27	Medium	II
	Mg	0	1	10	2.91	High	III

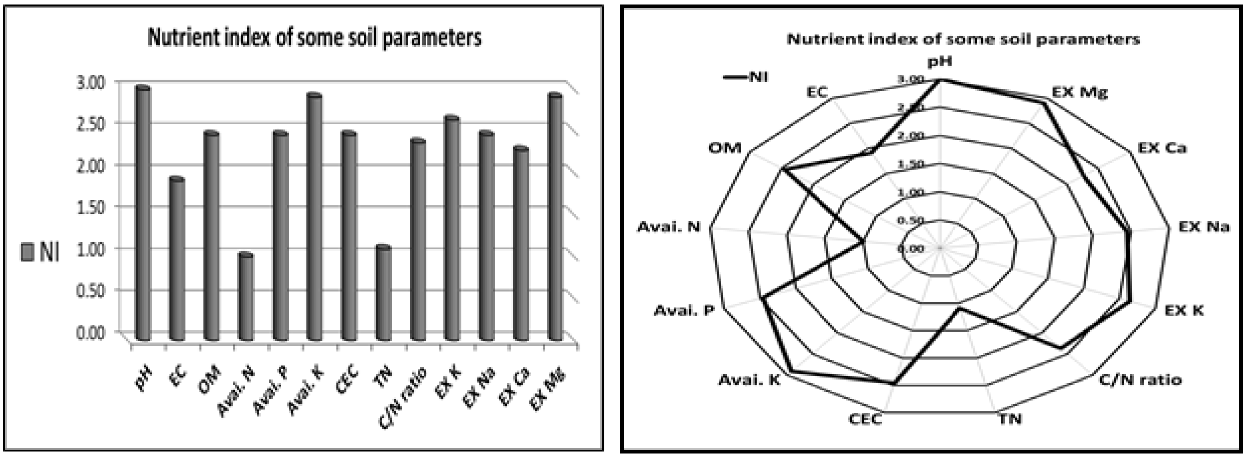

Fig. 14. Nutrient index Categories of soil parameters in the studied area.

CONCLUSIONS

Tracking changes of spatial distribution for soil properties is important to predicate with soil fertility status and support decision makes to develop fertility management programs, and helps improvement of agricultural practices to increase soil agricultural productivity. The presented discussions have demonstrated that spatial variability of soil properties changes from place to other and from time to other. The soils developed on alluvial deposits in the southern parts of the studied area were characterized by their higher values of clay, exchangeable Ca and Mg, OM, TN, C/N ratio, CEC and ESP. On the other hand, soils developed near the Mediterranean coast had higher values of sand, silt, exchangeable K and Na, bulk density, EC and pH. Based on the criteria for calculating nutrients index were observed improvement in some soil properties such as OM, available P, available K, CEC, C/N ratio, exchangeable K, exchangeable Na and exchangeable Mg. While, were watched to some extent degradation for available N, total nitrogen EC and exchangeable Ca.

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تقييم التباين المكاني لبعض خصائص التربة وحالة الخصوبة باستخدام دليل المغذيات ونظم المعلومات الجغرافية في منطقة بلقاس ، محافظة الدقهلية ، مصر

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من المهم تتبع التغيرات المكانية لمعرفة حالة خصوبة التربة. أجريت دراسة لاستكشاف التباين المكاني لبعض خصائص التربة باستخدام نظم المعلومات الجغرافية ، ومعرفة حالة خصوبة التربة باستخدام دليل المغذيات والوقوف علي التغيرات في التباين المكاني لخصائص التربة بالمقارنة مع دراسة سابقة ، مركز بلقاس ، محافظة الدقهلية ، مصر. تغطي المنطقة المدروسة حوالي 684 كم^2. بناءً على ذلك، تم جمع 11 عينة تربة سطحية طبقا لمواقع الدراسة السابقة باستخدام GPS. أشارت النتائج التي تم الحصول عليها إلى أن خرائط التغير المكاني لخصائص التربة تغيرت من موقع إلى آخر ومن وقت لآخر. عند مقارنة التباين المكاني لخصائص التربة بين الدراستين ، لوحظ انخفاض في الكثافة الظاهرية، النيتروجين والفوسفور الميسرين و السعة التبادلية الكاتيونية للدراسة الحالية. بينما لوحظ زيادة في ملوحة التربة ، تفاعل التربة (pH)، المادة العضوية والبوتاسيوم الميسر و نسبة الكربون للنيتروجين و النسبة المئوية للصوديوم المتبادل. بشكل عام ، لوحظ أن أعلي القيم كانت للطين ، الكالسيوم والماغنسيوم المتبادلين والمادة العضوية و النيتروجين الكلي و نسبة الكربون للنيتروجين و السعة التبادلية الكاتيونية و النسبة المئوية للصوديوم المتبادل في الأجزاء الجنوبية من المنطقة المدروسة. في المقابل ، تم رصد القيم الأدنى للرمل والسلت والبوتاسيوم والصوديوم المتبادلين ، والكثافة الظاهرية ، وملوحة وقلوية التربة في الأجزاء الجنوبية ، بينما لوحظت القيم الأدنى لعناصر النيتروجين والفوسفور والبوتاسيوم المتاحة في الأجزاء الشمالية. كان تقييم حالة خصوبة التربة باستخدام مؤشر المغذيات منخفضًا وفقًا للنيتروجين الكلي والنيتروجين الميسر. بينما كان متوسطًا وفقًا لمؤشر الملوحة والكالسيوم المتبادل. بالإضافة إلى ذلك ، كانت حالة خصوبة التربة مرتفعة وفقًا لمؤشر تفاعل التربة ، المادة العضوية ، الفوسفور الميسر ، البوتاسيوم الميسر ، السعة التبادلية الكاتيونية ، نسبة الكربون للنيتروجين ، البوتاسيوم والصوديوم والماغنسيوم المتبادلة.