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Relationship Mechanisms among Soils Fertility Degradation and Physicochemical Properties in Siwa Oasis Soils

Mohamed, M. S.*; Shimaa K. Ganzour and M. E. Abou-Kota

Soils, Water and Environmental Research Institute (SWERI), ARC, Egypt

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ABSTRACT

The recent soil fertility evaluations are evidence of the serious development challenges that many agricultural regions in Egypt; and with growing food demand, soil evaluation will become even more important for the regions in the coming years. The soils studied revealed that the highest ions concentration measured in soil paste extracts were Na^+ and Cl^- ions. The soil pH could be categorized as slightly to moderately alkaline. Alkaline soils, that have ESP more than 15% and high pH values. In general, most soils were relatively sandy loam. Else, CEC of the soils in the study area was between 3.16 to 24.96 cmolc kg^{-1}. Most soil study high content of $CaCO_3$ and considered as very slightly; slightly; moderately and highly gypsiferous. Data indicated that the available macro and micronutrients in the study area are low. Also, the exchangeable cations were significantly affected by recently environmental changes. This study was undertaken to investigate the spatial variability of selected soil properties using SFI modeling. Up to on the quantitative evaluation of SFI using spatial variability of soil data and modeling techniques is a very important operation. SFI in our study area is very poor fertility (S4= <20) according to classes and values of SFI**.** Pearson correlation coefficient was calculated to determine the significant positive correlation among SFI and soil pH; EC; $CaCO_3$; OM; total N; available of P, Fe, Mn and Cu; exchangeable of Ca, Na and K. In addition, the SFI is insignificantly and positively correlated with available Zn and exchangeable Mg.

Keywords: Soil fertility degradation (SFD), physicochemical properties, Siwa Oasis.

INTRODUCTION

Initially, the regions limited available water and soil fertility is behind the growing concern about food security and how feed a fast- growing population with changing eating habits. Then, soil fertility evaluation can help to improve crop production to increasing. In conclusion, agricultural development in land also has consequences for overall economic growth and development, as it affects the process of structural change. Soil fertility degradation (SFD), which is a reflection of the interaction of many environmental variables and affect the soil ability to crop production. Arid and semi-arid areas, the population density is increasing, pushing to increase productivity. Current environmental variables have a direct impact on physic- chemical soil properties, in addition to climate variables. Climate change has accelerated land degradation. SFD has been a major global issue since the twentieth century and has remained at the top of the list of international issues in the 21st century, (Imoke Eni, 2012). Further, he showed that the major causes of SFD include, land clearance poor farming practices, overgrazing, inappropriate irrigation, urban sprawl, and commercial development, land pollution including industrial waste and quarrying of stone, sand and minerals. High population density is not necessarily related to soil degradation, but it is what a population does to the land that determines the extent of degradation. Desertification can be defined as deterioration of producing soil fertility, either natural pasture or irrigated of dry farming lands, which result in decreasing of biological production of lands. It became less productive and may lose its fertility totally. The pastures may miss its natural green cover and replaced with undesired plants and toxic thistles, the trees and small trees would disappear and replaced with grass with less economically benefits which couldn't protect or fix the soil, (Abdul Ghafar, 2014).

The studies observe that the agriculture in Siwa oasis depends on the underground water flow from wells and springs throughout the oasis which are around 1275 wells and spring pumping about 255 million m3 water per year, out of such about 222 million m3 being utilized in irrigation and the rest flows to the low areas "lakes" That amounting 33 million m3 representing the destination of utilized water. It became clear that this pattern of utilizing water resources is one of most important reasons of desertification according to the results of the study. Since it has been indicted that the high salinity of soil, caused by irrational irrigation throughout the random digging of wells by farmers long time ago, resulted in increasing the rates of agriculture sewage, hence lead to increasing the issue of agricultural sewage which threaten thousands of cultivated properties in the oasis. Moreover, it composed four sewage swamps; Al Maraqi with area of 9 km^2 , Siwa amount in 32 km^2, Aghormy about 5 km^2 and kareshet with area of 16 km^2, (Abdul Ghafar, 2014). The cultivated crops in the depression are date palm and olive as cash crops, however; few areas are planted with citrus and some fruit orchards as well as alfalfa as intercropping (Hedia and Abd Elkawy, 2016).

* **Corresponding author.**
E-mail address: mahmoudaldemelawi@hotmail.com
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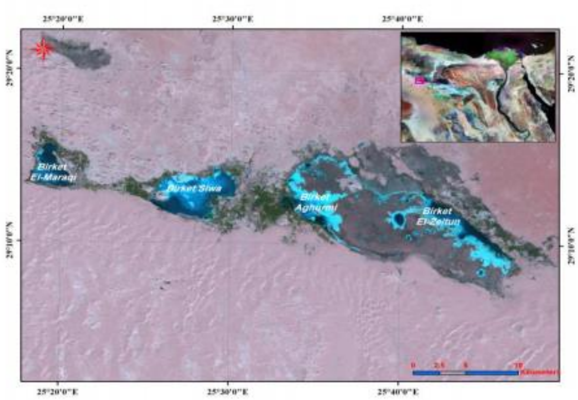
Siwa oasis has different land cover / land use units; *i.e.* salt marches, sabkha, cropland, grassland, bare land, urban, lakes, sand dunes, and hills. During the study period, a very several land cover change has taken place as a result of mismanagement of land resources. Change discovery at the study area explains the rapid increase of saline lakes and salt marshes, and the consequent hazards to the cultivated lands, roads and archeological sites and urban areas over the last three decades. These changes in land cover led to land degradation and water logging in many parts of the study area. In 1987, very slightly saline soil area was the largest in extent 34.1% of the total area whereas strongly saline, slightly saline and moderately saline soils covered 27.0%, 17.4% and 17.1%, respectively, of the total area. In 2017, strongly saline area increased as compared to 1987 and contributed for 39.1% of the total area, while very slightly, slightly saline and, moderately saline areas represented 18.9% and 13.2% and 14.9% respectively of the total area. Most of the salt affected areas were on shallow water table. The results indicate that long-term irrigation activities would affect agricultural potentiality of the area in the future, (Taher, 2017 and Abdel Rahman *et al*., 2019). The research supports the study of the state of soil fertility degradation, based on environmental variables (climatic changes, physical and chemical properties of soil, soil content of major elements), in order to reach the productivity increase; and to maintain the sustainability of agricultural lands in their fertility and thus their reflection on the quantity of production.

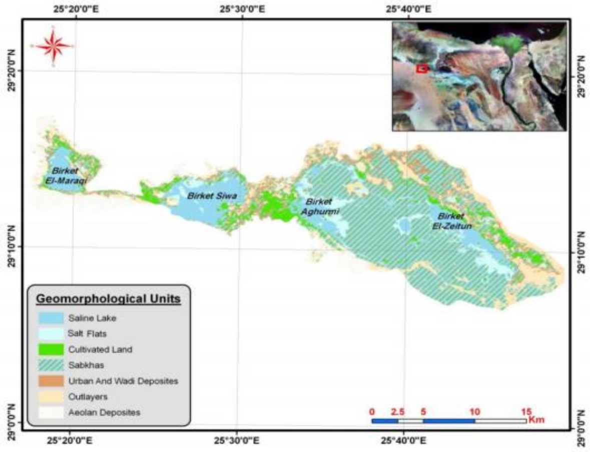
MATERIALS AND METHODS

The description of the study area: Siwa oasis is located northern western desert of Egypt, it is bound by longitudes 24º-26º 15' E and latitudes 29º-30º N, map (1), and it covers an area of 105000 ha^{-1}; it has an irregular elongate shape narrowing westwards (Rashed, 2016). The main activity in Siwa oasis is agriculture which depends on the groundwater that outflows from about 1199 wells and springs, giving a total annual discharge of about 255 million cubic meters. From this, about 222 million cubic meters are lost as evaporation and evapotranspiration, while the reminder goes to the natural lakes of Siwa oasis.



Map 1. location of Siwa Oasis

Geology of the Siwa oasis is essentially formations of the oldest to youngest are Middle Eocene, Oligocene, Miocene, recent and sub-recent deposits. Geomorophology is characterized by presece of four main physiographic units, *i. e.* sand dunes, lakes, high peripheries and hilly lands map (2), (Rashed, 2016).



Map 2. The Geomorphological map of Siwa Oasis

Field work: Forty four soil profiles were chosen to represent the soils of Siwa Oasis. Soil representative sample of the different layers of the studied soil profiles were taken for laboratory analyses.

Laboratory Analysis: The collected disturbed soil samples were air dried crushed and prepared for laboratory analyses, to determine some chemical and physical properties (USDA, 2004).

Soil analysis: Particle size distribution using the pipette method, calcium carbonate content using *Collin׳s calcimeter*, gypsum content by precipitation with acetone, soil pH was measured in the soil paste. Salinity as electrical conductivity ECs in the soil paste extract, cation exchange capacity and exchangeable cations, soluble cations and anions, SAR was determined according to Jackson, (1973). Total N, Available N and Available K were determined according to Page *et al*., (1982). Available P was determined according to Olsen *et al*., (1954), Available Fe, Mn, Zn and Cu were determined as suggested by Soltanpour and Schwab, (1977).

Computation of SFI: Mustafa and Orhan, (2014) revealed that soil fertility status can be evaluated directly or indirectly. Direct evaluations are carried out in the field under climatic and management conditions. Indirect evaluations consist basically in developing and applying models of varying complexity. One of the most suitable models is SFI model. SFI was calculated to qualitative soil fertility classes by means of parametric approach using 15 parameters for each soil sample point. To develop this model and determine threshold level of each SFI class, some literature such as Wolf, (1971); Lindsay and Norvell, (1978); Anonymous, (1992); Boruvka *et al*., (2005); Hazelton and Murphy, (2007) were used. The 15 parameters (diagnostic factors) are commonly implemented in soil physical and chemical properties and designated with letters from A to O (Table 1). Either parameters or factors are evaluated ranging between 10 and 100. The least favoritisms value of factor rating is 10 and the most beneficial value of factor rating is 100 for plant growth. In other words, the limiting nature of each SFI classes is taken into account by its effect in reducing productivity.

Table 1. The factor rating of each soil parameters.

Diagnostic Factors		Units	Factor rating				
			100	80	50	20	10
			Available macronutrient elements				
A-	N_{total}	g kg^{-1}	>3.2	3.2-1.7	0.9-1.7	0.9-0.45	<0.45
B-	$P_{avail.}$	mg kg^{-1}	>80	25.0-80.0	8.0-25.0	2.5-8.0	<2.5
C-	$K_{exc.}$	Cmol (+) kg^{-1}	0.28-0.74	0.74-2.56	0.13-0.28	>2.56	<0.13
D-	$Ca_{exc.}$	Cmol (+) kg^{-1}	17.5-50	5.75-17.5	1.19-5.75	>50.0	<1.19
E-	$Na_{exc.}$	Cmol (+) kg^{-1}	0.0-.20	0.21-0.30	0.31-0.70	0.71-2.0	>2.0
F-	$Mg_{exc.}$	Cmol (+) kg^{-1}	1.33-4.0	4.0-12.5	0.42-1.33	>12.5	<0.42
			Available micronutrient elements				
G-	$Mn_{avail.}$	mg kg^{-1}	14-50	4.0-14.0	50-170	>170	<4.0
H-	$Zn_{avail.}$	mg kg^{-1}	0.7-2.4	2.4-8.0	0.2-0.7	>8.0	<0.2
I-	$Fe_{avail.}$	mg kg^{-1}	2.0-4.5	1.0-2.0	1.0-0.2	>4.5	<0.2
J-	$Cu_{avail.}$	mg kg^{-1}	>0.2	-	-	-	<0.2
			Some soil physical and chemical characteristics				
K-	$CaCO_3$	g kg^{-1}	50-150	10.0-50.0	150-250	>250	0-10.0
L-	EC	dS m^{-1}	0-2.0	2.0-4.0	4.0-6.0	6.0-8.0	>8.0
M-	pH	(1:2.5)	6.5-7.5	7.5-8.5	5.5-6.5	4.5-5.5	<4.5->8.5
N-	OM	g kg^{-1}	>30	20.0-30.0	10-20	5.0-10.0	0-5.0
O-	Texture	%	CL,SCL,SiCL	VfSL, L, SiL, Si, <50% C	>50 % C, SC, SiC	SL, fSL	S, LS

N_{total}= total nitrogen, P_{avail}.= available phosphorus, K_{exc}.= exchangeable potassium, Ca_{exc}.= exchangeable calcium, Na_{exc}.= exchangeable sodium, Mg_{exc}.= exchangeable magnesium, Mn_{avail}.= available manganese, Zn_{avail}.= available zinc, Fe_{avail}.= available iron, Cu_{avail}.= available copper, EC= electric conductivity, OM= organic matter, CL= clay loam, SCL= sand clay loam, SiCL= silty clay loam, VFSL= very fine sandy loam, L= loam, SiL= silty loam, Si= silty, C= clay, SC= sand clay, SiC= silty clay, SL= sandy loam, fSL= fine sandy loam, S= sand, LS= Loamy sand.

SFI is calculated and using the value of factor rating for each factor as follows (equation), SFI of each soil sample point can be classified according to classes indicated in Table (2).

$$SFI = \left[Rmax \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times \ldots \times \frac{O}{100}} \right] \times 100$$

Rmax= maximum ratio, $\left[\frac{A+B+C+\cdots+O}{15}\right]$

A, B…= rating value for each diagnostic factor.

Table 2. Classes and values of soil fertility index

Class	Description	Soil Fertility Index (SFI)
S1	Good Fertility	> 80
S2	Moderate Fertility	50-80
S3	Marginal Fertility	20-50
S4	Poor Fertility	< 20

Statistical analysis: person correlation coefficients were calculated to determine the correlation among soil factors in different horizon. A one way analysis of variance (ANOVA) with Games Howell was applied to test in soils factors. The statistical analyses were conducted using Microsoft Excel 2010 and SPSS (v. 20), (SPSS, 2015).

RESULTS AND DISCUSSION

Electrical conductivity and concentration of soluble cations and anions: high EC can serve as an indication of salinity problems, which impede crop growth (inability to absorb water even when present), an increase of these ions in the soil can trigger an increase in osmotic pressure which decrease the potential plant water availability, leading to a cascade of events that reduce the plants. Soils with high EC resulting from high concentration of Na^+ generally have poor structure and drainage, and Na^+ becomes toxic to plants.

Saturated soil paste extracts and different soil to water ratios are commonly used in soil salinity studies and field remediation of salt- affected soils. The main characteristics of the soils studied revealed that the highest ion concentration measured in soil paste extracts were Na^+ and Cl^- ions. This is considered in the all soil profiles; except for profiles No. 9, 16, 25, 27, 32, 37, 42 and 44 (5.39; 6.51; 5.98; 3.71; 5.25; 6.13; 4.02 and 2.4 dS m^{-1}) respectively. The EC values ranged from 2.54 to 128.95 dS m^{-1} with an average value of 40.60 dS m^{-1}, Table (3).

The EC was significantly and positively correlated with OM, Gypsum, fine sand, silt, available K and available Zn (r= 0.261^{**}, r= 0.411^{**}, r= 0.192^{**}, r= 0.305^{**}, r= 0.206^{**}, and r= 0.44^{**}, respectively). The EC was negatively correlated with $CaCO_3$, coarse sand, available P, available Mn exchangeable and Mg (r= -0.237^{**}, r= -0.223^{**}, r= -0.226^{**}, r= -0.246^{**} and r= -0.275^{**}, respectively), Table (6) and figure (1).The pattern of soluble anions and cations indicated that NaCl, Na_2SO_4, $MgSO_4$ and $CaCl_2$ / $MgCl_2$ were the dominated the soluble salts of the studied soils in descending order. The cationic composition of the soil saturation extract of most soil layers was dominated by Na^+ followed by Ca^{+2} or Mg^{+2} and K^+. The anionic composition was characterized by the dominance of Cl^- followed by SO_4^{2-} or HCO_3^- while CO_3^{2-} anions were entirely absent. Alkaline soils, that have ESP more than 15% and high pH values.

The soil pH varied from 6.89 to 8.30, soil pH is a key factor that controls soil nutrient availability. The soil pH could be categorized as slightly alkaline to moderately alkaline. As it was well know that high sodium content gives rise to high pH in the soil.

The accumulation of alkalinity in a soil (as CO_3 and HCO_3 of Na^+, K^+, Ca^{+2} and Mg^{+2}) occurs when there is insufficient after flowing through the soils to leach soluble salts. This may be due to arid conditions, or poor internal soil drainage. The soil pH was significantly and positively correlated with coarse sand, available Cu (r= 0.340^{**}, r= 0.169^{**}, respectively). The soil pH was negatively correlated with EC, CEC, OM, fine sand, clay content and exchangeable K (r= -0.315^{**}, r= -0.312^{**}, r= -0.306^{**}, r= -0.34^{**}, r= -0.306^{**}, r= -0.306^{**} and respectively), Table (6) and figure (2).

Physicochemical properties of soils studies: in general, most soils were relatively sandy loam in profiles (2, 3, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 36, 37 and 38). On the other hand, some profiles were sand in profiles (10, 11, 39, 40, 41, 42, 43 and 44). The rest of the profiles were sand clay loam in profiles (4, 5, 15, 16 and 35); loamy sand in profiles (1, 8, 9, 30, 33 and 34); loam in profile (17). In terms of soil texture at all land uses, no statistical difference was observed at the surface soil layer, indicating the homogeneity of soil forming processes and the similarity of parent materials. Hence, the differences in terms of soil properties at various agricultural land uses could be attributed to variations in management practices at the study area. The dominant particle size fractions were sand and reflect the sandstone parent materials from which the soils were derived.

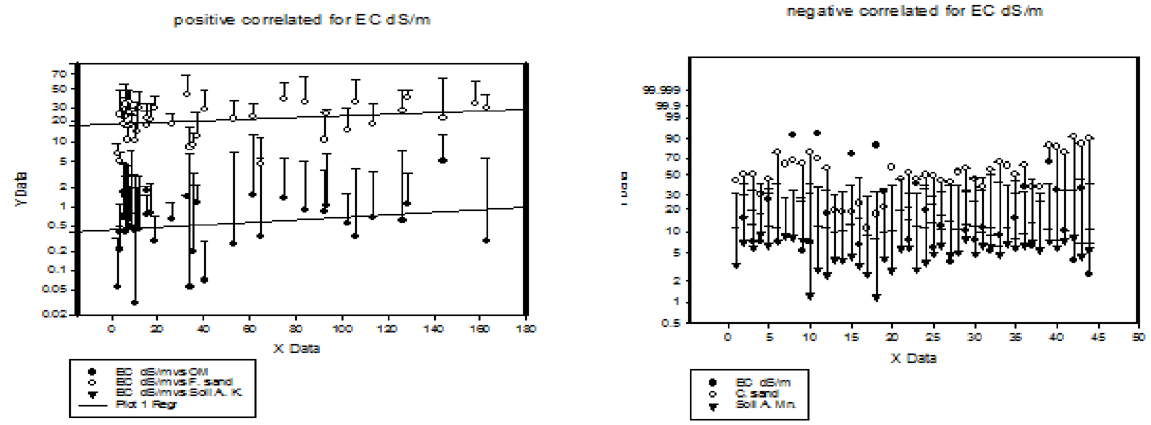


Fig. 1. Box plots of different soil properties and soil salinity for studied area.

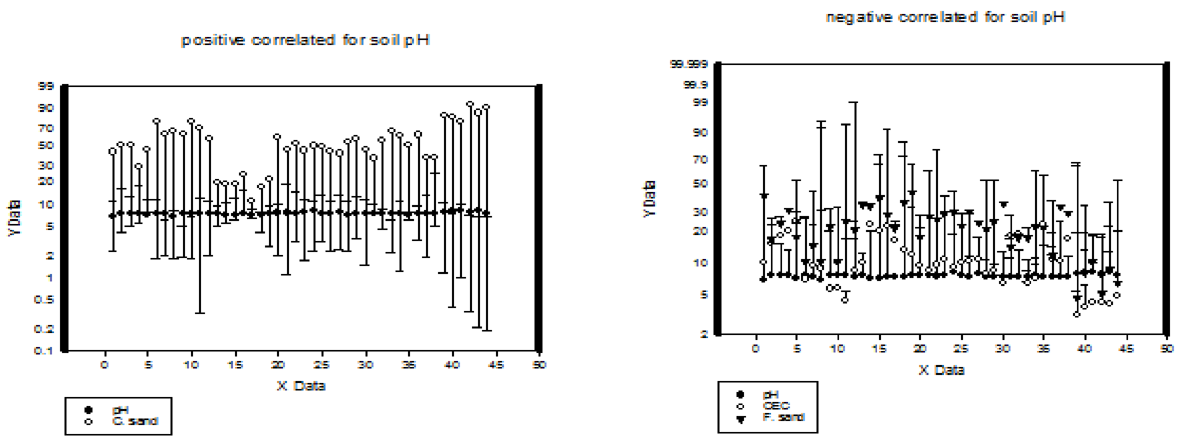


Fig. 2. Box plots of different soil properties and pH soil for studied area.

The coarse sand was significantly and positively correlated with available K, available Fe and available Mn at (r= 0.202*, r= 0.246** and 0.187*, respectively). The coarse sand was negatively correlated with fine sand, silt, clay, Na exchangeable, K exchangeable (r= -0.762**, r= -0.72**, r= -0.654**, r= -0.359** and r= -0.653**, respectively). The fine sand was significantly and positively correlated with silt, clay, Na and exchangeable K at (r= 0.348**, r= 0.207**, r= 0.288** and 0.207*, respectively). The fine sand was negatively correlated with available Fe and available Mn at (r= -0.195* and r= -0.224**, respectively). The silt was significantly and positively correlated with clay, Na and exchangeable K exchangeable at (r= 0.247**, r= 0.199**and 0.247*, respectively). The silt was negatively correlated with available Mn at (r= -0.212**). The clay was significantly and positively correlated with Na and exchangeable and K exchangeable at (r= 0.280**and 1.0**, respectively). The silt was negatively correlated with available N, available K and available Fe at (r= -0.182*, r= -0.233** and r= -0.186*, respectively), Table (6).

The analysis of variance results revealed that cations exchange capacity (CEC) of the soils was between 3.16 to 24.96 $Cmol_c\ kg^{-1}$ (Table 4). Besides, the amount and types of clay particles also the determinant factor on the CEC of soils. The CEC was significantly and positively correlated with OM, $CaCO_3$, fine sand, silt, clay, Ca exchangeable, Na exchangeable and K exchangeable at (r= 0.215**, r= 0.228**, r= 0.284**, r= 0.273**, r= 0.908**, r= 0.206**, r= 0.340** and 0.908**, respectively). The CEC was negatively correlated with coarse sand, available K, available Fe (r= -0.664**, r= -0.261** and r= -0.18*, respectively), Table (6) and figure (3).

The analysis of variance results revealed that the soil organic matter (OM) contents were low. The results showed that values where between 0 to 4.98% (Table 4). The positive relationship between soil OM and CEC confirm that the more soil organic matter. The more potential of the nutrient reservoir of the soil, and exchangeable basic cations on soil complex site, and vice versa in the case of lack of OM. The OM was significantly and positively correlated with gypsum, fine sand, silt, clay, total N, available Fe, K exchangeable at (r= 0.220**, r= 0.226**, r= 0.336**, r= 0.238**, r= 0.171*, r= 0.304** and 0.238**, respectively). The OM was negatively correlated with coarse sand, available P, Mg exchangeable (r= -0.369**, r= -0.304** and r= -0.19*, respectively), Table (6) and figure (4).

Table 3. The weight profiles mean to soluble cations and anions for soil samples collected.

Profile No.	Profile Deep(cm)	pH	EC dS m^{-1}	Soluble cations (mmolc L^{-1}) Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Soluble anions (mmolc L^{-1}) Cl^{-}	CO_3^{2+}	HCO_3^{-}	SO_4^{2-}	ESP %
1	40	6.89	128.95	211.90	767.65	242.90	2654.05	3670.00	1.50	0.00	205.00	65.63
2	150	7.72	15.39	32.18	13.66	2.73	98.02	109.50	1.90	0.35	34.83	22.99
3	70	7.65	7.26	16.36	9.70	1.31	48.38	57.00	2.20	0.73	16.54	15.56
4	150	7.64	7.39	22.61	24.49	1.46	52.23	47.00	2.10	1.10	50.58	13.60
5	110	7.33	26.18	87.97	85.43	9.44	11763.33	716.00	1.60	0.60	11227.97	52.85
6	95	7.65	7.40	63.32	66.83	6.32	196.80	286.00	2.73	0.93	43.61	26.82
7	90	7.57	102.37	132.40	141.10	32.38	18833.43	1377.33	1.13	0.00	17763.12	43.70
8	75	7.05	92.57	146.33	749.88	103.76	1951.93	2625.67	2.07	0.00	328.30	95.12
9	75	7.70	5.39	19.53	6.16	2.00	40.83	37.00	3.70	1.20	36.41	20.64
10	95	7.65	7.40	17.10	16.15	1.59	51.72	48.00	1.73	0.73	41.02	10.24
11	35	7.64	93.75	90.97	65.29	41.93	86150.00	6270.00	1.50	0.00	80079.68	17.14
12	130	7.50	17.19	38.25	35.08	4.59	136.67	121.33	2.43	1.13	96.83	99.13
13	30	7.78	106.30	85.70	159.80	45.68	41600.00	1730.00	2.00	0.00	40163.18	12.75
14	35	7.19	158.30	119.04	1017.40	158.00	3436.70	3220.00	1.60	0.00	1512.74	20.46
15	65	7.30	75.30	137.47	317.37	24.89	13550.33	1326.67	1.67	0.00	12701.73	66.78
16	80	7.53	6.51	26.51	29.25	1.96	46.39	47.33	2.00	0.67	54.10	92.06
17	30	7.38	144.10	71.46	519.45	58.86	85639.56	2435.00	5.20	0.00	83849.13	4.57
18	49	7.40	84.10	97.60	220.60	38.22	2014.30	520.00	1.60	0.00	1849.12	73.25
19	110	7.64	32.83	60.61	78.79	19.39	310.77	360.67	2.47	0.00	106.43	67.19
20	45	7.80	113.70	109.50	15.51	110.25	2072.20	2020.00	1.10	0.00	286.36	28.30
21	52	7.79	126.50	95.20	32.10	101.03	2620.00	2325.00	1.50	0.00	521.83	61.13
22	90	7.63	7.48	34.27	15.10	1.67	48.58	40.33	3.33	0.60	55.36	78.50
23	150	7.87	40.60	102.80	5.82	30.14	410.05	401.00	1.00	0.20	146.61	6.84
24	150	8.24	19.18	42.62	4.05	17.89	190.10	159.50	0.70	0.70	93.76	43.94
25	115	7.66	5.98	12.23	49.15	1.48	42.04	57.33	1.73	0.93	44.90	28.93
26	120	7.55	11.75	46.19	24.44	6.08	120.38	112.00	1.80	0.90	82.39	29.26
27	120	7.90	3.71	7.63	3.28	1.08	28.30	28.00	2.47	1.00	8.82	18.01
28	100	7.37	53.40	107.94	43.25	41.24	881.87	780.00	1.20	0.00	293.10	11.07
29	95	7.59	10.08	37.10	15.29	2.99	73.76	82.67	2.47	0.27	43.74	53.05
30	75	7.50	7.68	33.55	4.55	3.09	96.17	70.40	2.73	0.40	63.83	13.05
31	120	7.54	11.32	36.91	26.74	2.97	80.92	99.25	1.75	0.30	46.23	18.35
32	60	7.47	5.25	47.31	37.39	3.74	74.35	109.00	2.20	0.67	50.92	13.47
33	150	7.53	8.72	35.24	22.34	2.22	56.56	65.33	2.00	0.93	48.09	10.90
34	45	7.64	61.83	186.47	185.97	13.64	1493.19	1450.67	2.53	0.53	425.53	9.90
35	55	7.40	15.20	39.68	56.68	7.69	127.60	148.67	2.93	1.40	78.66	56.61
36	20	7.46	36.90	71.44	201.30	13.35	313.04	540.00	2.80	0.60	55.73	14.76
37	70	7.59	6.13	14.28	5.12	1.46	36.84	36.67	3.13	1.13	16.77	25.34
38	45	7.49	162.75	73.35	114.40	53.14	3436.65	2880.00	2.00	0.90	794.63	11.79
39	45	8.05	64.90	50.48	366.91	39.14	1057.80	848.50	3.30	0.20	662.33	67.91
40	75	8.18	34.28	43.07	32.80	20.47	357.30	86.50	2.10	0.60	364.43	13.56
41	65	8.30	10.28	35.95	12.23	10.73	80.26	39.05	2.20	0.00	97.91	18.76
42	95	7.89	4.02	9.49	4.60	2.12	33.12	40.50	4.40	0.00	4.43	17.70
43	25	8.29	35.70	48.12	110.10	15.11	797.00	588.00	3.00	0.00	379.33	13.01
44	65	7.68	2.54	8.33	6.91	0.97	17.61	17.50	6.30	0.00	10.01	53.38

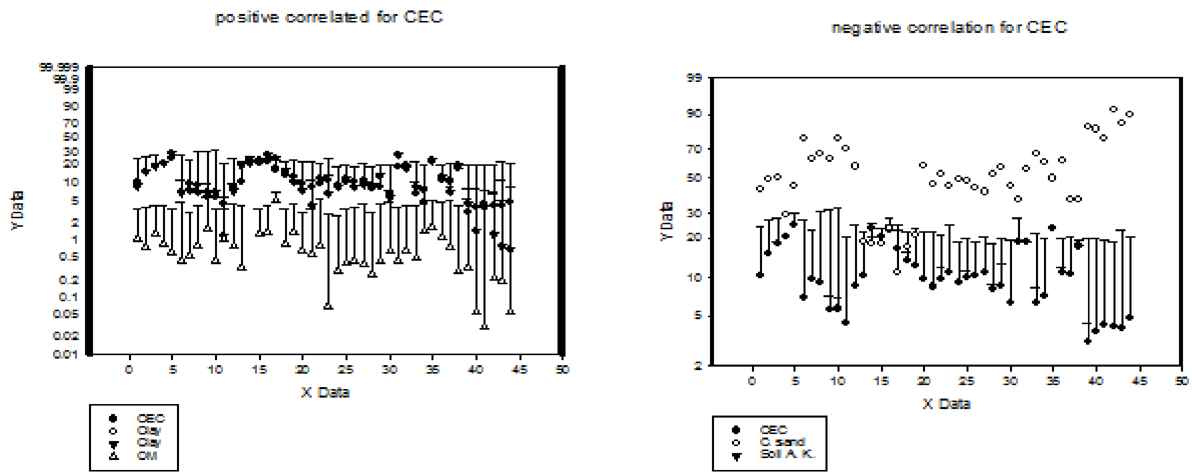


Fig. 3. Box plots of different soil properties and CEC for studied area.

According to (London, 1991 and Mulugeta *et al*., 2019) classification, the soil classified as none calcareous soil when $CaCO_3$ contents are less than 0.5% and considered as calcareous soil when it is 0.5% and above. Based on this classification, the study area was characterized by high content of $CaCO_3$ in most soil study, which indicates that the presence of calcareous soil with the exception of the profiles (3, 5, 9, 19, 23, 24, 25, 27, 35 and 44) which indicates that the presence of no calcareous soil, where the average results are between 0.03 to 0.405%. The $CaCO_3$ was significantly and positively correlated with clay, total N, available Mn, K exchangeable at (r= 0.253**, r= 0.220**, r= 0.173* and 0.253**, respectively). The $CaCO_3$ was negatively correlated with available N, Fe and Zn (r= -0.162*, r= -0.166* and r= -0.211**, respectively), Table (6) and figure (5).

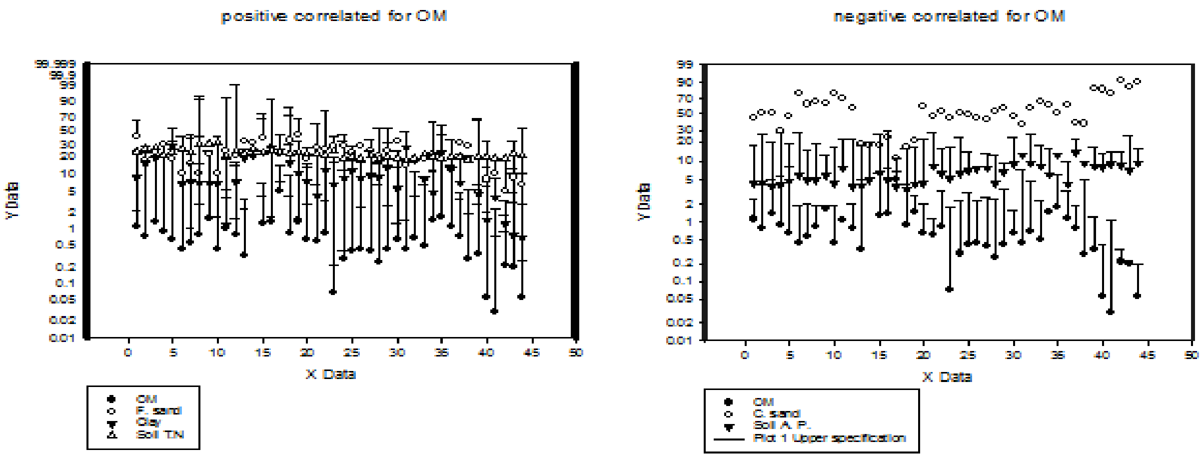


Fig. 4. Box plots of different soil properties and OM for studied area.

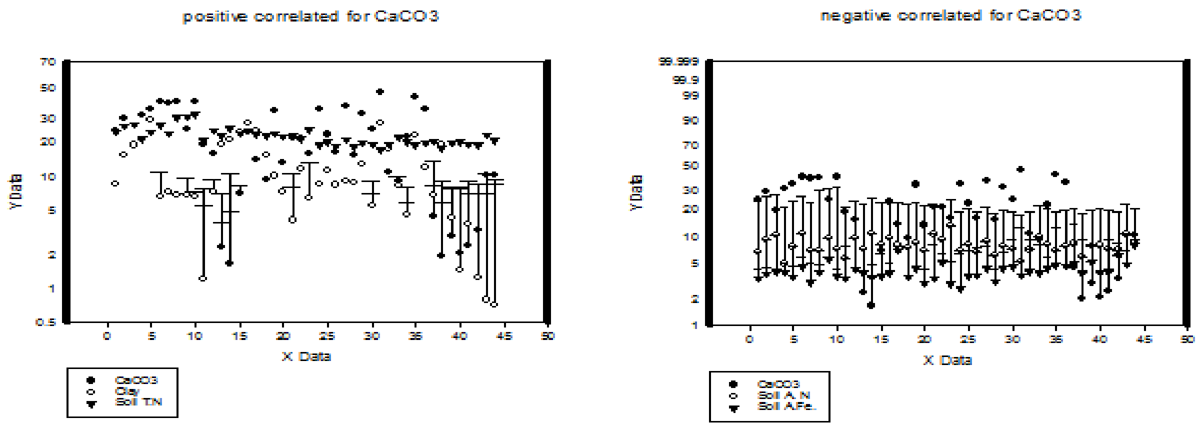


Fig. 5. Box plots of different soil properties and $CaCO_3$ for studied area.

Harmful effect of gypsum depends on soil gypsum content, its distribution, presence of water resources, and the soil permeability to allow water movement in soil. Risk appears when salt groundwater rise up through soil by capillary action and through tectonic cracks up to the ground surface. Where, water rising gypsum salts to deposit at the surface and crystallized there and this process makes soil surface to swell because of crystallization pressure. According to (Al-Baraznji, 1973 and FAO, 1990) classification, the soil classified as non-gypsiferous (0-0.3%); very slightly gypsiferous (0.31-3%); slightly gypsiferous (3.1-10%); moderately gypsiferous (10.1-25%) and highly gypsiferous (25.1-50%). Based on classification the study area was considered as very slightly gypsiferous in profiles (13, 14, 38, 40 and 41); slightly gypsiferous in profiles (4, 15, 18, 33, 39 and 42); moderately gypsiferous in profiles (1, 3, 11, 12, 16, 17, 20, 21, 22, 23, 25, 26, 28, 34, and 43) and highly gypsiferous in profiles (2, 4, 5, 6, 7, 8, 9, 10, 19, 24, 26, 29, 30, 31, 35 and 36). The gypsum was significantly and positively correlated with available K and Zn at (r= 0.172* and 0.267**, respectively). The gypsum was negatively correlated with $CaCO_3$ and Total N (r= -0.358** and r= -0.206**, respectively), Table (6) and figure (6).

Soil macro and micronutrients: according to the results of analysis of (ANOVA) revealed that total N was significantly and positively correlated with OM, $CaCO_3$, available N and Ca exchangeable at (r=0.171*, r= 0.22**, r= 0.498** and r= 0.273**, respectively). On the other hand, the total N was negatively correlated (r= -0.206**, r= -0.551**, r= -0.172**, r= -0.184* and r= -0.19*) with gypsum, available P, available Mn, available Cu and Mg exchangeable, respectively (Table 6). Considering the interaction of land studied with soil depth, the highest 32.78 mg kg^{-1}, the lowest 17.18 mg kg^{-1} and medium 22.29 mg kg^{-1} (Table 5).

Data presented in Tables (5&6) and figure (7) show that available N of the studied soil profiles are generally low, it tends to decrease in coarse texture soils. Data demonstrate that the distribution of available N range between 5.05 to 13.27 mg kg^{-1}, and average 22.29 mg kg^{-1}. Available N was significantly and positively correlated with total N and Ca exchangeable (r= 0.498** and r= 0.182*). Also, available N was negative correlated (r= -0.162*, r= -0.182*, r= -0.208**, r= -0.222** and r= -0.182*) with $CaCO_3$, clay, available P & Mn and K exchangeable.

Data in (Tables) indicated that the available content of P in the study area ranged between 3.52 to 13.81 mg kg^{-1} and average 6.61 mg kg^{-1}, presumable due to either the high adsorption and/or precipitation with $CaCO_3$, MnO_2 or iron oxides. Available P was significantly and positively correlated with Mg exchangeable (r= 0.24**). Also, available P was negative correlated (r= -0.226**, r= -0.193*, r= -0.551**, r= -0.208** r= -0.225** and r= -0.189*) with EC, OM, total N, available N, available K and Ca exchangeable, shown (Tables 5& 6) and figure (8).

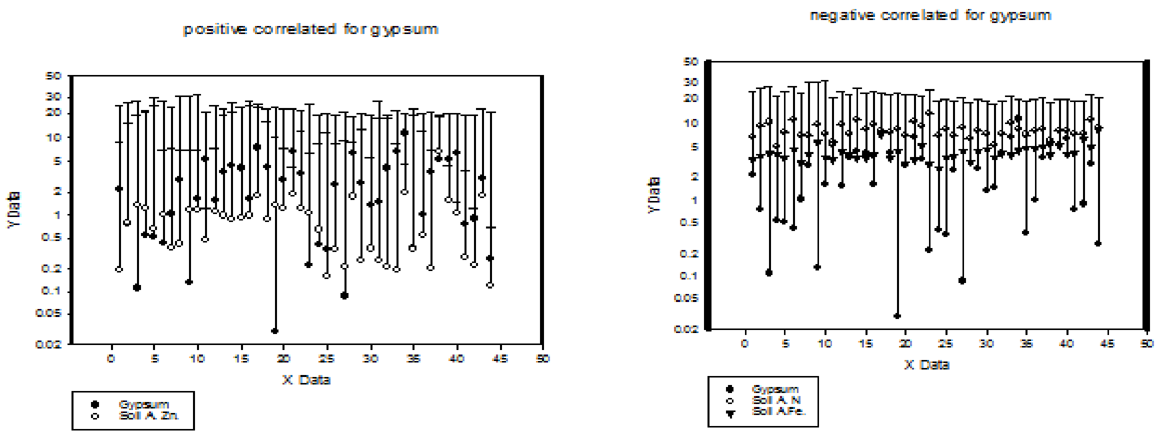


Fig. 6. Box plots of different soil properties and gypsum for studied area.

Table 4. Descriptive of the some soil physicochemical by results weight means for soil samples collected.

Profile No.	Profile Deep (cm)	Particle size distribution (%) C. Sand	F. Sand	Silt	Clay	Texture	CEC (Cmolc kg-1)	OC %	OM %	$CaCO_3$ %	Gypsum %
1	40	42.99	40.88	7.35	8.78	LS	10.36	0.64	1.11	2.220	24.92
2	150	49.78	17.24	17.56	15.43	SL	15.44	0.44	0.76	0.759	30.35
3	70	50.74	23.93	6.51	18.82	SL	18.53	0.78	1.35	0.110	19.29
4	150	29.75	31.18	18.23	20.85	SCL	20.61	0.52	0.90	0.540	32.36
5	110	45.28	17.99	6.55	30.18	SCL	24.97	0.37	0.64	0.517	35.63
6	95	77.20	10.64	5.26	6.91	LS	7.08	0.26	0.45	0.437	41.06
7	90	62.73	14.88	14.87	7.53	SL	9.69	0.32	0.56	1.047	39.75
8	75	67.06	10.64	15.26	7.05	LS	9.11	0.48	0.82	2.927	40.64
9	75	63.01	22.51	7.37	7.12	LS	5.71	0.95	1.64	0.130	25.43
10	95	77.20	10.64	5.26	6.91	S	5.73	0.26	0.45	1.657	41.06
11	35	69.94	24.98	3.87	1.22	S	4.38	0.61	1.05	5.345	18.90
12	130	57.87	20.74	13.96	7.43	LS	8.57	0.46	0.79	1.550	15.82
13	30	18.88	35.05	26.77	19.30	SL	10.45	0.20	0.34	3.630	2.41
14	35	18.32	33.95	27.01	20.72	SCL	23.58	0.00	0.00	4.400	1.68
15	65	18.08	38.89	19.21	23.82	SCL	20.31	0.77	1.33	4.137	7.23
16	80	23.64	28.50	19.74	28.12	SCL	22.83	0.82	1.41	1.667	23.85
17	30	11.06	21.71	42.28	24.95	L	16.76	2.89	4.98	7.555	14.07
18	49	17.06	36.06	31.29	15.60	SL	13.76	0.50	0.87	4.210	9.65
19	110	20.95	43.19	25.51	10.36	SL	12.43	0.84	1.44	0.030	34.97
20	45	58.90	18.11	15.50	7.51	SL	9.76	0.39	0.67	2.845	13.57
21	52	45.92	27.70	22.20	4.20	SL	8.57	0.35	0.60	6.595	21.29
22	90	52.58	25.85	9.55	12.03	SL	9.77	0.49	0.84	3.437	21.11
23	150	44.61	28.85	20.01	6.54	SL	11.09	0.04	0.07	0.220	16.18
24	150	49.64	29.78	11.93	8.66	SL	9.15	0.17	0.30	0.405	35.69
25	115	48.19	22.85	17.40	11.55	SL	10.19	0.24	0.41	0.353	22.98
26	120	43.58	30.19	17.60	8.64	SL	10.55	0.26	0.44	2.510	16.40
27	120	41.51	24.32	24.73	9.44	SL	11.20	0.23	0.40	0.087	38.01
28	100	53.17	21.21	16.62	8.99	SL	8.12	0.15	0.26	6.540	15.38
29	95	57.33	24.55	5.15	12.96	SL	8.73	0.25	0.43	2.667	32.83
30	75	45.45	35.25	13.61	5.69	LS	6.41	0.37	0.64	1.333	25.46
31	120	36.88	14.33	20.74	28.05	SCL	18.78	0.26	0.45	1.525	46.73
32	60	55.91	17.80	8.92	17.37	SL	18.95	0.40	0.68	4.127	11.07
33	150	66.40	17.88	7.29	8.43	LS	6.46	0.29	0.49	6.673	9.38
34	45	60.78	22.39	12.13	4.70	LS	7.33	0.86	1.48	11.410	22.21
35	55	49.89	21.99	5.34	22.77	SCL	23.59	1.01	1.74	0.380	43.55
36	20	62.08	12.00	13.67	12.25	SL	11.05	0.67	1.15	1.000	36.18
37	70	37.15	33.36	22.36	7.13	SL	10.73	0.44	0.77	3.713	4.58
38	45	37.02	29.44	14.29	19.27	SL	17.50	0.17	0.29	5.42	2.01
39	45	84.16	4.64	6.76	4.45	S	3.16	0.20	0.35	5.31	3.02
40	75	82.54	8.27	7.69	1.50	S	3.76	0.03	0.06	6.34	2.15
41	65	77.08	10.52	8.53	3.88	S	4.26	0.02	0.03	0.75	2.48
42	95	91.88	5.10	1.77	1.26	S	4.16	0.12	0.22	0.91	3.40
43	25	85.70	8.80	4.70	0.80	S	4.00	0.12	0.20	3.07	10.45
44	65	89.81	6.48	3.01	0.71	S	4.79	0.03	0.06	0.27	10.58

SCL= sand clay loam, L= loam, SL= sandy loam, S= sand, LS= Loamy sand.

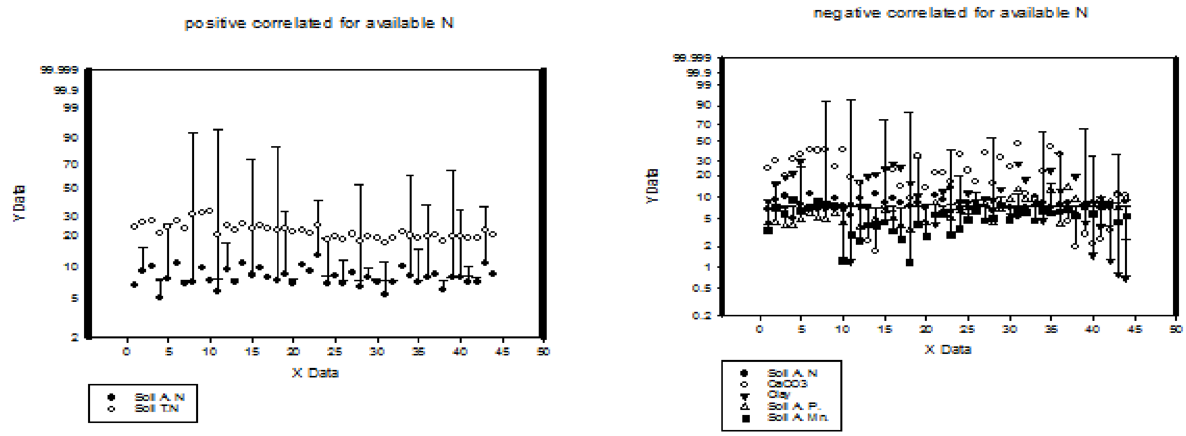


Fig. 7. Box plots of different soil properties and total nitrogen for studied area.

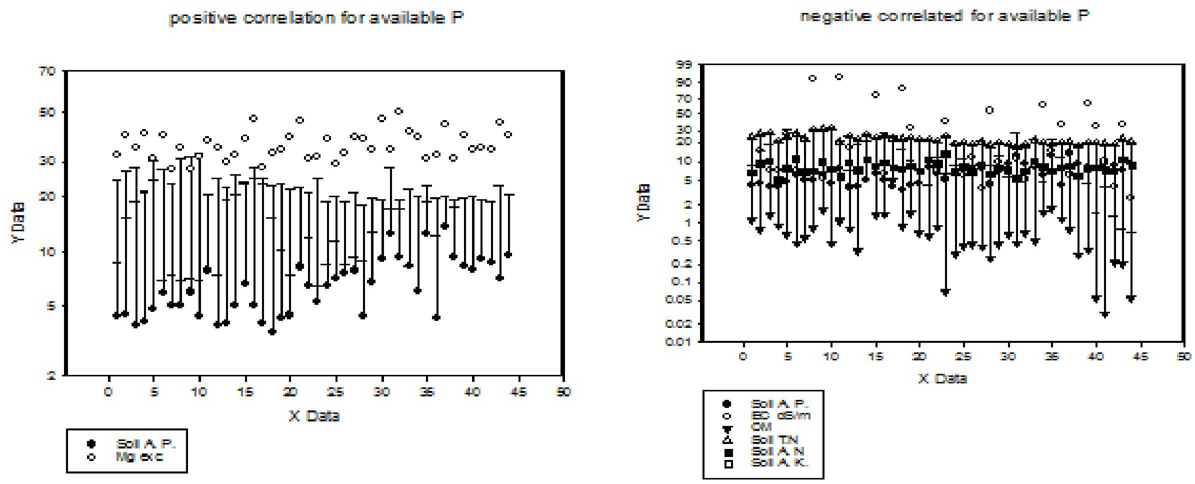


Fig. 8. Box plots of different soil properties and available P for studied area.

The spatial distribution of available K between 142.63 to 255.68 mg kg^{-1} and average 200.43 mg kg^{-1}, the results reported here suggest lower sorption of K by sand. This observation is in agreement with the results of (Abou Kota, 2012 & 2016 and Ganzour, 2015). Referring to results in Table (6) and figure (9) a significant positive correlation among available K and EC, gypsum, coarse sand, available of Fe, Zn, Cu at (r= 0.206**, r= 0.172*, r= 0.202* r= 0.178*, r= 0.301**and r= 0.246**, respectively), where, CEC, clay, available P, available Mn, exchangeable of Ca, Mg, Na, K significant negatively correlated with available K (r= -0.261**, r= -0.233**, r= -0.185*, r= -0.271** r= -0.440**, r= -0.389**, r= -0.157* and r= -0.233**).

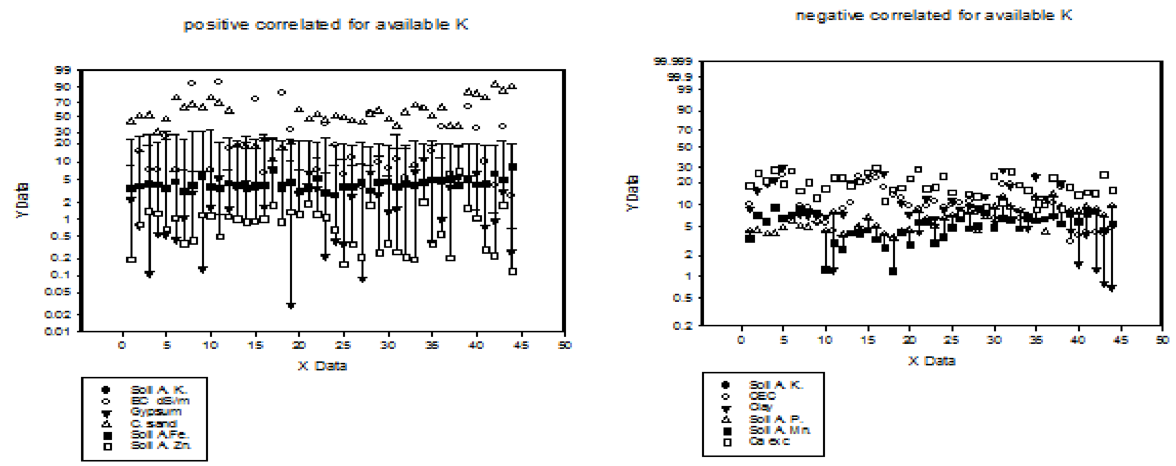


Fig. 9. Box plots of different soil properties and available K for studied area.

Data identified that the available content of Fe in the study area ranged between 8.28 to 2.68 mg kg^{-1} and average 4.18 mg kg^{-1}. Available Fe was significantly and positively correlated with OM, coarse sand, available K, available Zn and available Cu (r= 0.304**, r= 0.246**, r= 0.178*, r= 0.301** and r= 0.246**, respectively). Also, available Fe was negative correlated (r= -0.166*, r= -0.195*, r= -0.271**, r= -0.44**, r= -0.389** r= -0.157* and r= -0.233**) with $CaCO_3$, fine sand, clay, available Mn, Ca exchangeable, Mg exchangeable, Na exchangeable and K as shown (Tables 5& 6) and figure (10). Nutrient mobility, accumulation and behavior were obviously evident from the above data and correlation and determination coefficient ions which reflect the magnitude of nutrient antagonism and selectivity that may govern, to a great extent, element translocation from soil to plant.

Data identified that the available content of Mn in the study area ranged between 1.02 to 9.25 mg kg^{-1} and average 5.46 mg kg^{-1}. Available Mn was significantly and negative correlated with EC, fine sand, silt, total N, available N and available K (r= -0.246^{**}, r= -0.244^{**}, r= -0.212^{**}, r= -0.172^{*}, r= -0.222^{**} and r= -0.271^{*}, respectively) Also, available Fe was positively correlated (r= 0.173^{*}, r= 0. 187^{*} and r= 0.225^{**}) with $CaCO_3$, coarse sand and available P, shown (Tables 5& 6) and figure (11).Data recognized that the available content of Zn in the study area ranged between 0.12 to 6.84 mg kg^{-1} and average 1 mg kg^{-1}. Available Zn was significantly and negative correlated with $CaCO_3$ (r= -0.211^{**}) Also, available Zn was positively correlated (r= 0.44^{**}, r= 0. 267^{**}, r= $0.301^{**}$and r= 0.387^{**}) with EC, gypsum, available K and Na exchangeable, shown (Tables 5& 6) and figure (12). While the low available Zn amount in desert plain soils developed of the Eocene limestone may be attributed to the relatively high CaCO3 content

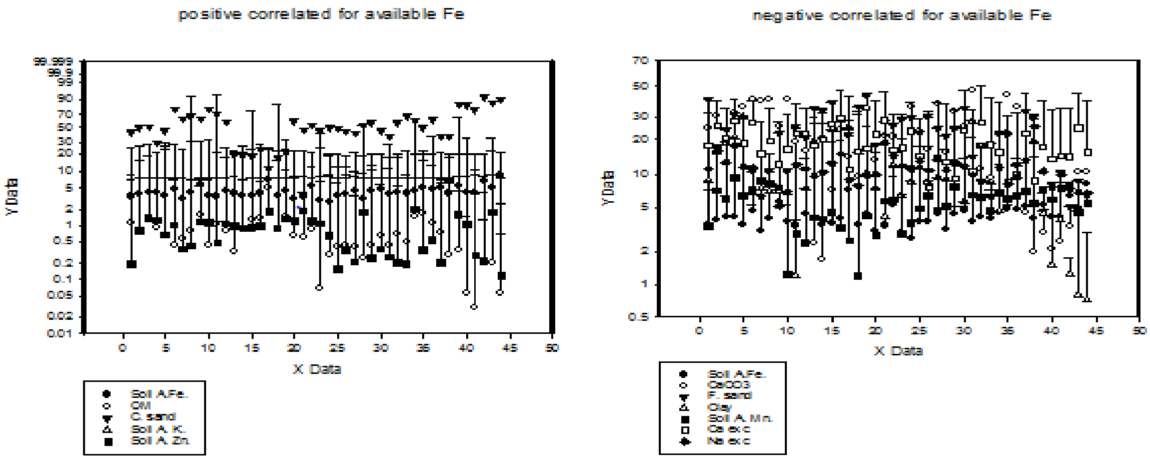


Fig. 10. Box plots of different soil properties and available Fe for studied area.

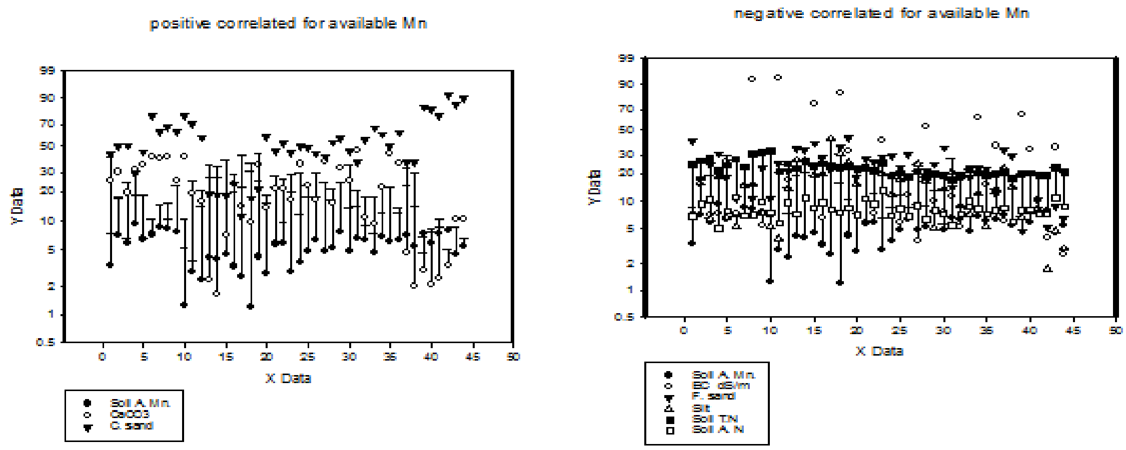


Fig. 11. Box plots of different soil properties and available Mn for studied area.

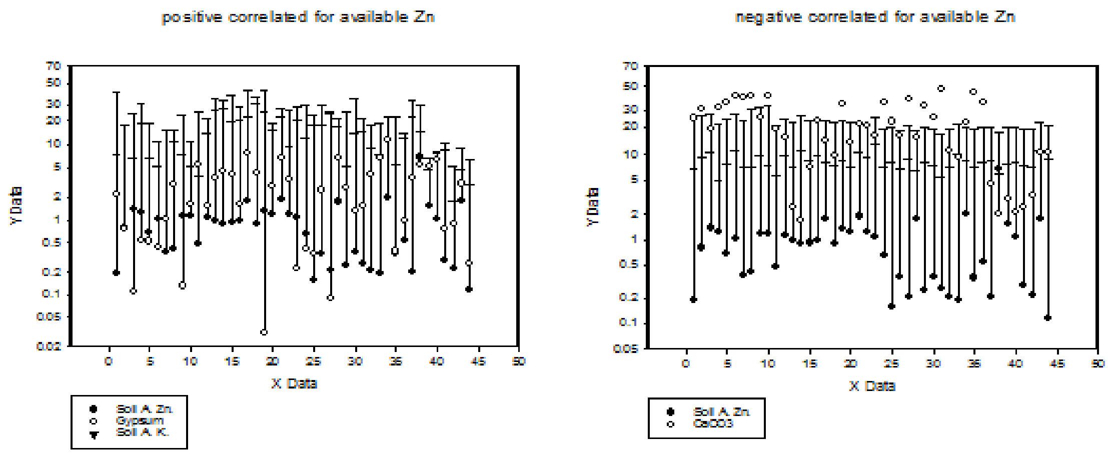


Fig. 12. Box plots of different soil properties and available Zn for studied area.

Data recognized that the available content of Cu in the study area ranged between 0.35 to 1.33 mg kg^{-1} and average 0.87 mg kg^{-1}. Available Cu was significantly and negative correlated with total N, Ca exchangeable and Mg exchangeable (r= -0.184*, r= -0.263** and r= -0.302**) Also, available Cu was positively correlated (r= 0.169* and r= 0.246**) with pH and available K, shown (Tables 5& 6) and figure (13).

The analysis of variance results indicated that the exchangeable Ca was significantly affected by recently environmental changes. The mean values of exchangeable Ca in the study area were between 7.62 to 29.55 cmol$_c$ kg^{-1} with an average value of 17.87 cmol$_c$ kg^{-1}. The exchangeable Ca was significantly and positively correlated with CEC, clay, total N, exchangeable Mg and exchangeable Na at (r= 0.206**, r= 0.273**, r= 0.169*, r= 0.725** and r= 0.301**, respectively). Also, the exchangeable Ca was negatively correlated (r= -0.189*, r= -0.440** and r= -0.203* respectively) with available of P, K, Fe and Cu, shown (Tables 5& 6) and figure (14).

Data documented that the exchangeable Mg in the study area ranged between 27.31 to 50.41 cmol$_c$ kg^{-1} and average 34.74 cmol$_c$ kg^{-1}. The exchangeable Mg was significantly and negative correlated with total EC, OM, total N, available K and available Cu (r= -275**, r= -0.19* r= -389**, and r= -0.302**) Also, exchangeable Mg was positively correlated (r= 0.24**, r= 0.725** and r= 0.264**) with exchangeable Ca and exchangeable Na, shown (Tables 5& 6) and figure (15).

The mean values of exchangeable Na in the study area were between 5.19 to 25.41 cmol$_c$ kg^{-1} with an average value of 17.87 cmol$_c$ kg^{-1}. The exchangeable Ca was significantly and positively correlated with CEC, fine sand, silt, clay, available Zn, exchangeable Ca and exchangeable Mg at (r= 0.34**, r= 0.288**, r= 0.28**, r= 0.387** r= 0.301**and r= 0.264**, respectively). Also, the exchangeable Na was negatively correlated (r= -0.359**, r= -0.157* and r= -0.158* respectively) with coarse sand, available K and available Fe (Tables 5& 6) and figure (16).

Table 5. Descriptive of the macro & micro elements and exchangeable elements by results weight means for soil samples collected.

Profile No.	Profile Deep (cm)	Macro and micro elements (mg kg^{-1}) Total N	Avail. N	Avail. P	Avail. K.	Avail. Fe.	Avail. Mn.	Avail. Zn.	Avail. Cu.	Cations exchangeable (cmol$_c$ kg^{-1}) Exch. Ca	Exch. Mg	Exch. Na	Exch. K
1	40	24.18	6.82	4.34	190.75	3.48	3.44	0.19	0.58	17.87	32.10	11.17	2.37
2	150	26.74	9.37	4.53	159.38	3.88	7.16	0.80	0.67	25.76	40.00	16.11	4.17
3	70	27.78	10.41	3.92	201.67	4.18	5.93	1.38	0.73	20.38	34.62	12.75	5.09
4	150	21.28	5.05	4.08	146.08	4.08	9.25	1.24	0.75	28.08	40.31	17.56	5.64
5	110	24.08	7.85	4.84	226.71	3.58	6.48	0.67	1.13	18.63	30.86	11.65	8.16
6	95	27.35	11.12	5.99	190.37	4.71	7.28	1.03	0.91	27.34	39.58	11.54	1.87
7	90	23.27	7.04	5.06	181.60	3.11	8.77	0.37	0.95	15.07	27.31	6.36	2.04
8	75	31.11	7.19	5.01	203.33	4.05	8.19	0.42	0.77	19.40	34.63	8.19	1.91
9	75	31.74	9.88	6.00	234.68	5.68	7.59	1.16	0.82	12.31	27.54	5.19	1.93
10	95	32.78	7.51	4.40	219.31	3.71	1.24	1.15	0.83	16.50	31.73	6.96	1.87
11	35	20.74	5.73	7.94	236.34	3.48	2.91	0.48	0.86	22.32	37.55	12.09	0.33
12	130	24.64	9.63	3.87	206.17	4.41	2.42	1.11	0.73	22.51	34.74	11.19	2.01
13	30	22.29	7.28	4.00	178.39	3.98	4.09	1.00	0.87	17.85	30.08	9.69	5.22
14	35	26.01	11.00	5.01	201.85	3.58	3.96	0.90	0.74	20.00	32.23	10.38	5.60
15	65	23.48	8.47	6.61	173.82	3.65	4.54	0.91	0.95	26.47	38.70	12.47	6.44
16	80	24.80	9.79	5.05	171.78	3.98	3.33	1.00	0.60	29.55	46.80	15.08	7.60
17	30	23.17	8.16	3.96	239.13	7.18	2.53	1.80	0.91	11.05	28.30	8.93	6.75
18	49	22.61	7.60	3.52	200.00	3.58	1.20	0.88	0.73	15.79	33.04	7.95	4.22
19	110	23.53	8.52	4.29	210.41	4.45	4.22	1.34	1.09	16.75	34.01	9.68	2.80
20	45	22.11	7.10	4.43	167.67	3.08	2.83	1.22	0.72	22.00	39.25	10.01	2.03
21	52	22.56	10.77	8.32	156.49	3.48	5.76	1.90	1.00	28.50	45.75	18.78	1.13
22	90	21.17	9.38	6.45	191.57	5.31	5.91	1.22	0.91	16.26	31.13	14.58	3.25
23	150	25.06	13.27	5.27	255.68	2.98	2.92	1.09	1.25	17.00	31.87	11.90	1.77
24	150	18.82	7.03	6.48	206.67	2.68	3.64	0.65	1.11	23.44	38.31	11.06	2.34
25	115	20.11	8.32	7.19	188.03	3.71	4.89	0.16	1.33	14.44	29.31	13.09	3.12
26	120	18.70	6.91	7.70	202.44	3.78	6.42	0.36	0.89	7.62	32.96	10.87	2.33
27	120	20.82	9.03	7.92	191.47	4.45	4.79	0.21	1.00	13.75	39.08	13.56	2.55
28	100	18.19	6.40	4.38	234.94	3.18	5.15	1.76	1.12	12.73	38.07	10.93	2.43
29	95	19.79	8.00	6.83	207.35	4.45	7.77	0.25	0.84	9.12	34.45	12.53	3.51
30	75	19.08	7.29	9.29	211.32	4.71	4.90	0.37	0.80	23.65	47.06	11.82	1.54
31	120	17.18	5.39	12.73	183.16	3.73	6.52	0.26	0.75	10.64	34.06	9.92	7.58
32	60	19.04	7.26	9.50	195.41	4.18	6.26	0.21	0.35	26.99	50.41	8.74	4.70
33	150	21.97	10.18	8.38	142.63	3.98	4.70	0.19	0.60	18.15	41.56	6.38	2.28
34	45	20.14	8.35	6.12	254.44	4.51	6.85	2.03	1.00	15.54	38.95	11.38	1.27
35	55	18.99	7.21	12.65	181.89	4.91	6.01	0.35	1.22	8.63	31.00	8.13	6.16
36	20	19.79	8.00	4.25	211.41	4.78	6.38	0.54	0.91	10.00	32.38	9.45	3.31
37	70	20.28	8.49	13.81	153.20	5.11	7.07	0.20	0.86	22.20	44.58	13.27	1.93
38	45	17.79	6.00	9.44	242.73	3.98	5.49	6.84	0.82	8.75	31.12	25.41	5.21
39	45	19.73	7.95	8.33	200.43	5.28	7.34	1.57	0.57	17.27	39.64	10.59	1.20
40	75	19.95	8.16	8.00	229.19	4.08	5.93	1.05	1.09	13.65	33.99	7.65	0.41
41	65	19.11	7.32	9.29	172.23	4.18	7.48	0.28	0.80	14.46	34.81	10.03	1.05
42	95	19.03	7.25	8.76	202.26	6.38	8.14	0.22	1.28	14.20	34.54	7.41	0.34
43	25	22.79	11.00	7.21	197.88	4.98	4.52	1.78	1.31	24.57	44.92	6.95	0.22
44	65	20.53	8.75	9.55	220.00	8.28	5.46	0.12	0.91	15.55	40.06	6.86	0.19

Data documented that the exchangeable K in the study area ranged between 0.19 to 8.16 $cmol_c\ kg^{-1}$ and average 2.8 $cmol_c\ kg^{-1}$. The exchangeable K was significantly and negative correlated with pH, coarse sand, available N, available K and available Fe (r= -0.306**, r= -0.653** r= -182*, r= -0.233** and r= -0.186* respectively) Also, exchangeable K was positively correlated (r= 0.908**, r= 0.238**, r= 0.253** , r= 0.207**, r= 0.247**, r= 1.0** and r= 0.28**) with CEC, OM, $CaCO_3$, fine sand, silt, clay, exchangeable Na, shown (Tables 5& 6) and figure (17)

Table 6. Pearson's Correlation matrix of physicochemical properties of soils in studied area.

	EC	CEC	OM	Gyps.	$CaCO_3$	Coarse Sand	Fine Sand	Silt	Clay	Total N	Avail. N	Avail. P	Avail. K	Avail. Fe	Avail. Mn	Avail. Zn	Avail. Cu	Ca Exch	Mg. Exch	Na. Exch	K. Exch
pH	-.315**	-.312**	-.306**	-0.09	-0.15	.340**	-.306**	-0.11	-.306**	-0.14	0.14	0.13	-0.02	0.09	0.08	-0.02	.169*	0.05	0.14	0.02	-.306**
EC		-0.00	.261**	.411**	-.237**	-.223**	.192*	.305**	-0.02	0.05	-0.06	-.226**	.206**	-0.14	-.246**	.440**	-0.05	-0.10	-.275**	0.09	-0.02
CEC			.215**	-0.13	.228**	-.664**	.284**	.273**	.908**	-0.02	-0.14	-0.01	-.261**	-.180*	0.10	0.01	-0.06	.206**	0.08	.340**	.908**
OM				.220**	0.05	-.369**	.226**	.336**	.238**	.171*	0.05	-.193*	0.16	.304**	-0.15	0.06	-0.07	-0.08	-.190*	-0.07	.238**
Gyps.					-.358**	-0.04	0.05	0.13	-0.11	-.206**	-0.06	0.03	.172*	-0.01	-0.09	.267**	-0.12	-0.05	0.13	-0.02	-0.11
$CaCO_3$						-0.06	-0.07	-0.04	.253**	.220**	-.162*	-0.09	-0.08	-.166-*	.173*	-.211**	0.09	-0.02	-0.13	-0.03	.253**
C.S							-.762**	-.72-**	-.654**	0.09	0.12	0.12	.202*	.246**	.187*	-0.10	0.06	-0.12	-0.01	-.359**	-.653**
F.S								.348**	.207**	-0.12	-0.08	-0.10	-0.11	-.195-*	-.224**	0.12	-0.00	0.13	0.04	.288**	.207**
Silt									.247**	-0.04	-0.00	-0.15	-0.10	-0.15	-.212**	0.05	-0.02	0.02	-0.03	.199*	.247**
Clay										-0.03	-.182*	-0.02	-.233**	-.186*	0.05	0.03	-0.11	0.11	-0.00	.280**	1.000**
T.N											.498**	-.551**	0.07	-0.01	-.172*	-0.01	-.184*	.273**	-.190*	-0.13	-0.03
A.N												-.208**	0.11	0.14	-.222**	0.01	0.02	.169*	0.02	0.01	-.182*
A.P													-.185*	0.15	.225**	-0.09	0.03	-.189*	.240**	-0.01	-0.02
A.K														.178*	-.271**	.301**	.246**	-.440-**	-.389**	-.157*	-.233-**
A.Fe															0.08	-0.02	-0.03	-.203*	-0.07	-.158*	-.186*
A.Mn																-0.11	0.01	-0.01	0.10	0.12	0.05
A.Zn																	0.01	-0.09	-0.12	.387**	0.03
A.Cu																		-.263**	-.302**	-0.09	-0.11
Ca.exch																			.725**	.301**	0.11
Mg.exch																				.264**	-0.00
Na.exch																					.280**

The pair(s) of variables with positive correlation coefficients and P values below 0.050 tends to increase together. For the pairs with negative correlation coefficients and P values below 0.050, one variable tends to decrease while the other increases. For pairs with P values greater than 0.050, there is no significant relationship between the two variables. Main effect means within a columns followed by the different letter (s) are significantly different from each other at ≤ 0.05; *= significant at ≤ 0.05 and **= significant at ≤ 0.01.

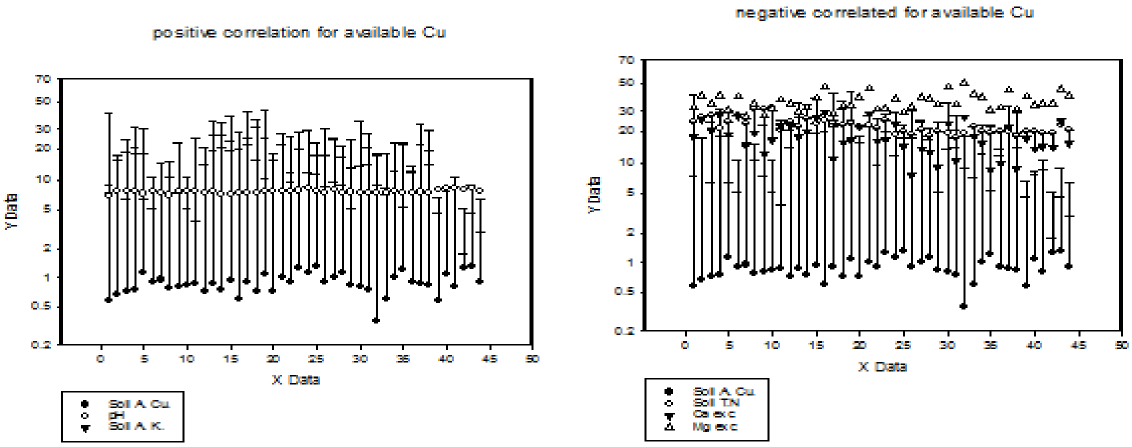


Fig. 13. Box plots of different soil properties and available Cu for studied area.

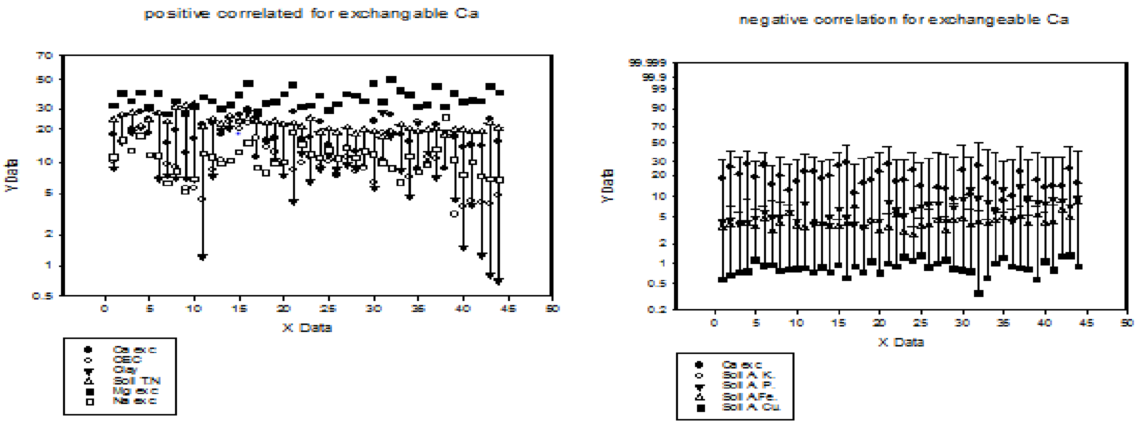


Fig. 14. Box plots of different soil properties and exchangeable Ca for studied area.

Distribution of SFI with spatial variability: soil fertility in systems under arid and the study shows the efficiency of these tools analyze the information on SFI in various domains in an also very easy to update data involved in these techniques with more accuracy and reliability. Consequently, finding of this study showed that the most of the soil properties had strong spatial dependency and statistical modeling is very useful tool to determine the spatial variability structure and spatial dependency of soil properties. The quantitative evaluation of SFI using spatial variability of soil data and modeling techniques is a very important operation. SFI in our study area is very poor fertility (S4= <20) according to classes and values of soil fertility index (Mustafa and Orhan, 2014), this result is confirmed by the results obtained from Table (7).This study was undertaken to investigate the spatial variability of selected soil properties, such as soil pH, EC, $CaCO_3$, OM, total N, available P, available Fe, available Mn, available Zn, available Cu, exchangeable Ca, exchangeable Mg, exchangeable Na and exchangeable K. in addition, using soil fertility index "high technical".

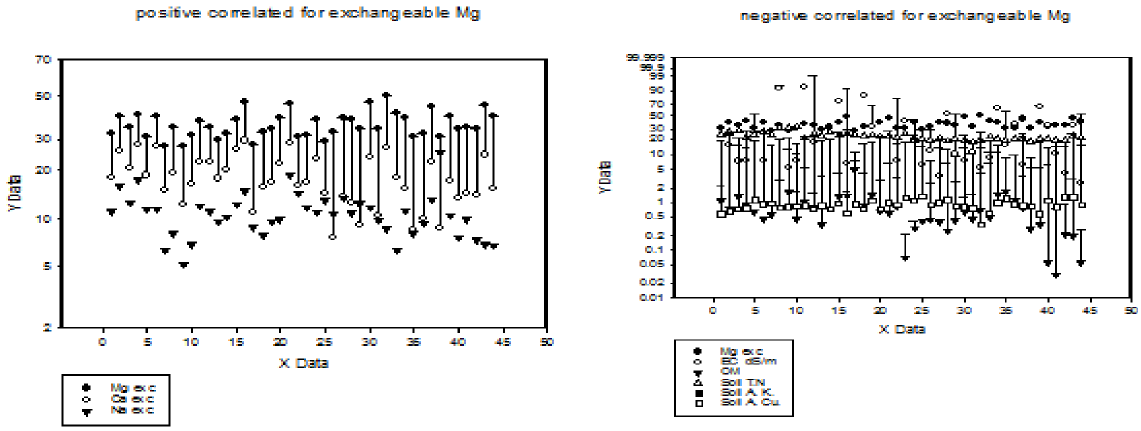


Fig. 15. Box plots of different soil properties and exchangeable Mg for studied area.

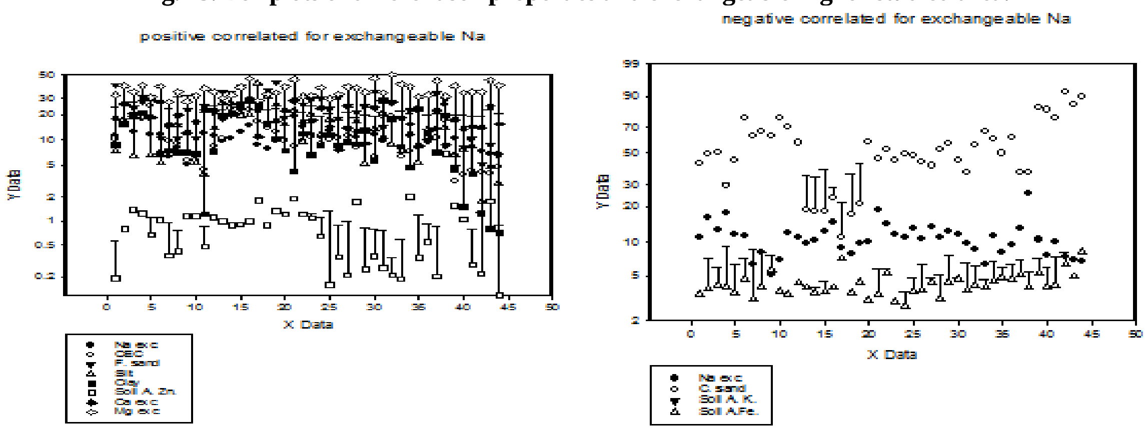


Fig. 16. Box plots of different soil properties and exchangeable Na for studied area.

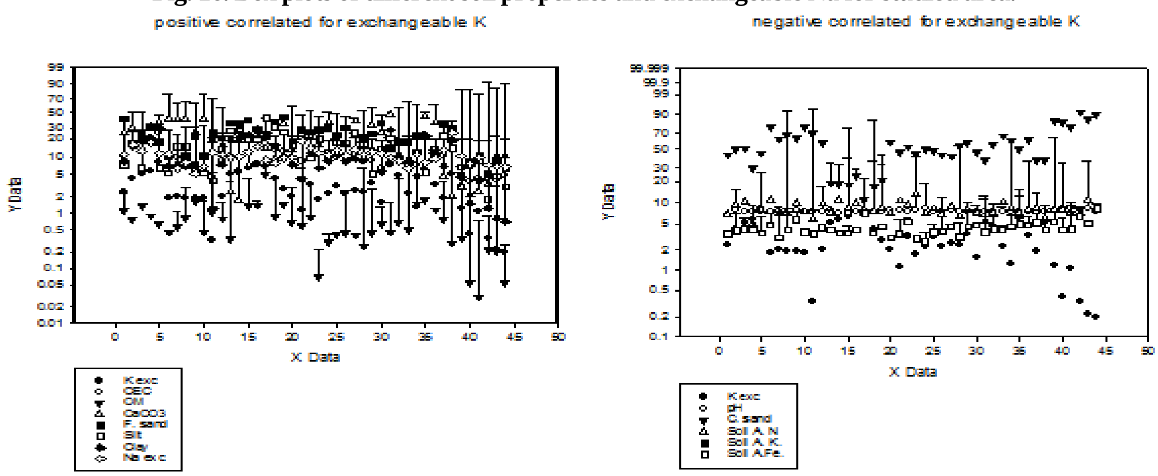


Fig. 17. Box plots of different soil properties and exchangeable K for studied area.

Pearson correlation coefficient was calculated to determine the a significant positive correlation among SFI and (soil pH, EC, $CaCO_3$, OM, total N, available P, available Fe, available Mn, available Cu, exchangeable Ca, exchangeable Na and exchangeable K) at (r= 0.065**, r= 0.292^{**}, r= 0.489^{**}, r= 0.275^{**}, r= 0.088^{*}, r= 0.199^{*}, r= 0.30^{**}, r= 0.453^{**}, r= 0.104^{*}, r= 0.065^{*}, r= 0.188^{*}, r= 0.115^{*} and r= 0.202^{**}, respectively). In addition, Pearson correlation coefficient indicated that the SFI is insignificantly and positively correlated with available Zn and exchangeable Mg at (r= 0.043 and r= 0.028, respectively), this result is confirmed by the results obtained from Table (8).

Table 7. Descriptive of factor rating of soil parameters, classes and values of soil fertility index for the studied area.

Profile No.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	SFI	SFI Class
1	10	20	80	100	10	20	10	10	100	100	80	10	80	50	10	0.47	PF
2	10	20	20	100	10	20	80	100	100	100	80	10	80	20	20	2.08	PF
3	10	20	20	100	10	20	80	100	100	100	80	20	80	50	20	4.89	PF
4	10	20	20	100	10	20	80	100	100	100	80	20	80	20	100	7.34	PF
5	10	20	20	100	10	20	80	50	100	100	80	10	100	20	100	3.91	PF
6	10	20	80	100	10	20	80	100	100	100	80	20	80	10	10	3.13	PF
7	10	20	80	80	10	20	80	50	100	100	80	10	80	20	20	2.59	PF
8	10	20	80	100	10	20	80	50	100	100	80	10	100	20	10	2.38	PF
9	10	20	80	80	10	20	80	100	100	100	80	50	80	50	10	10.50	PF
10	10	20	80	80	10	20	10	100	100	100	80	20	80	10	10	0.88	PF
11	10	20	80	100	10	20	10	50	100	100	80	10	80	50	10	1.10	PF
12	10	20	80	100	10	20	10	100	100	100	80	10	100	20	10	1.16	PF
13	10	20	20	100	10	20	80	100	100	100	10	10	80	10	20	0.47	PF
14	10	20	20	100	10	20	10	100	100	100	10	10	100	10	100	0.43	PF
15	10	20	20	100	10	20	80	100	100	100	10	10	100	50	100	3.13	PF
16	10	20	20	100	10	20	10	100	100	100	80	20	80	50	100	3.91	PF
17	10	20	20	80	10	20	10	100	100	100	80	10	100	100	80	3.58	PF
18	10	20	20	80	10	20	10	100	100	100	10	10	10	20	20	0.06	PF
19	10	20	20	80	10	20	80	100	100	100	80	10	80	50	20	2.98	PF
20	10	20	80	100	10	20	10	100	100	100	80	10	80	20	20	1.45	PF
21	10	50	80	100	10	20	80	100	100	100	80	10	80	20	20	7.34	PF
22	10	20	20	80	10	20	80	100	100	100	80	20	80	20	20	2.59	PF
23	10	20	80	80	10	20	10	100	100	100	80	10	80	10	20	0.88	PF
24	10	20	80	100	10	20	10	50	100	100	80	10	80	10	20	0.67	PF
25	10	20	20	80	10	20	80	10	100	100	80	20	80	10	20	0.50	PF
26	10	20	80	80	10	20	80	50	100	100	80	10	80	10	20	1.81	PF
27	10	20	80	80	10	20	80	50	100	100	80	80	80	10	20	5.60	PF
28	10	20	80	80	10	20	80	100	100	100	80	10	100	10	20	3.13	PF
29	10	20	20	80	10	20	80	50	100	100	80	10	80	10	20	0.83	PF
30	10	50	80	100	10	20	80	50	100	100	80	20	100	20	10	5.60	PF
31	10	50	20	80	10	20	80	50	100	100	80	10	80	10	100	3.41	PF
32	10	50	20	100	10	20	80	50	100	100	80	50	100	20	20	6.11	PF
33	10	50	80	100	10	20	80	10	100	100	10	20	80	10	10	0.47	PF
34	10	20	80	80	10	20	80	100	100	100	80	10	80	50	10	4.48	PF
35	10	50	20	80	10	20	80	550	100	100	80	10	100	50	100	48.11	PF
36	10	20	20	80	10	20	80	50	100	100	80	10	100	50	20	2.26	PF
37	10	50	80	100	10	20	80	10	100	100	10	20	80	20	20	0.96	PF
38	10	50	20	80	10	20	80	80	100	100	10	10	80	10	20	0.58	PF
39	10	50	80	80	10	20	80	100	100	100	10	10	80	10	10	1.01	PF
40	10	20	80	80	10	20	80	100	100	100	10	10	80	10	10	0.61	PF
41	10	50	80	80	10	20	80	50	100	100	10	10	80	10	10	0.67	PF
42	10	50	80	80	10	20	80	50	100	100	10	50	80	10	10	1.58	PF
43	10	20	80	100	10	20	80	100	100	100	80	10	80	10	10	2.19	PF
44	10	50	80	80	10	20	80	10	100	100	80	80	80	10	10	2.73	PF

A= total nitrogen, B= available phosphorus, C= exchangeable potassium, D= exchangeable calcium, E= exchangeable sodium, F= exchangeable magnesium, G= available manganese, H= available zinc, I= available iron, J= available copper, K= calcium carbonate, L= electric conductivity, M= soil pH, N= organic matter, O= texture, PF= poor fertility, SFI= soil fertility index.

The obtained results showed a small fluctuation in pH soil, these results indicated that the soil is slightly and moderately alkaline to neutral. These results probably related to carbonate nature. Geologically, this area is characterized by the Quaternary deposits covering the most of study area. Dominant formations are lime- stone, marls and sandstone. Soils, as natural corps, are inherently heterogeneous, due to the many factors that contribute to their diagnosis. These soils are strongly affected by salts, according to results. The problem of soil salinization is particularly prevalent in arid and semi-arid areas where evapotranspiration exceeds annual precipitation and irrigation is necessary to meet water requirements. In arid and semi-arid regions monitoring of soil salinity is essential for efficient soil and water management of agricultural lands (Aldabaa *et al*., 2015 and Hakima *et al*., 2019).

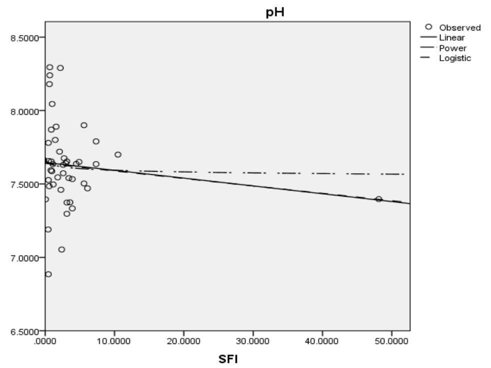
Consequently, in our area, factors affecting soil physicochemical properties, including geological, climatic and hydrological contexts, due to existence of different factors, the statistical methods were applied to the physicochemical data, in order to separate the area into homogenous zones in order to optimize their management.

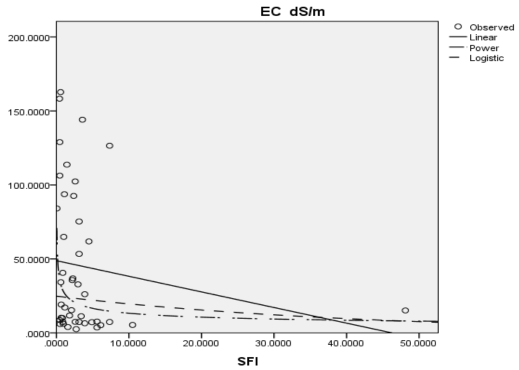
The study shows the efficiency of these tools to analyze the information on SFI in various domains in an integrated manner to understand the system. It is also very easy to update data involved in these techniques with more accuracy and reliability. Consequently, findings of this study showed that the most of the soil properties had strong spatial dependency and statistical modeling is very useful tool to determine the spatial variability structure and spatial dependency of soil properties.

It is urgent recommended that the probable spatio-temporal changes in spatial variability of soil properties originating from the implementing of variable rate fertilizer and other agricultural input should be investigated in cultivated areas. Next to this study, more research should be devoted to these important topics, in particular validation of usefulness of SFI in decision making and implantation.

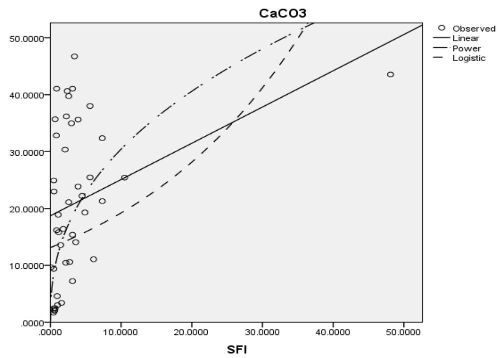
Table 8. Regression for models with dependent variable soil fertility index and the studied soil variables.

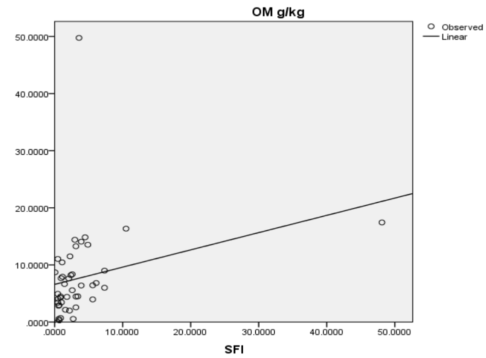
Model Summary							
R	R Square	Adjusted R Square	Std. Error of the Estimate	R	R Square	Adjusted R Square	Std. Error of the Estimate
.065*	.004	-.020-	.039	.292**	.085	.063	1.206
The independent variable is SFI. The dependent variable is ln(pH).				The independent variable is SFI. The dependent variable is ln(EC).			



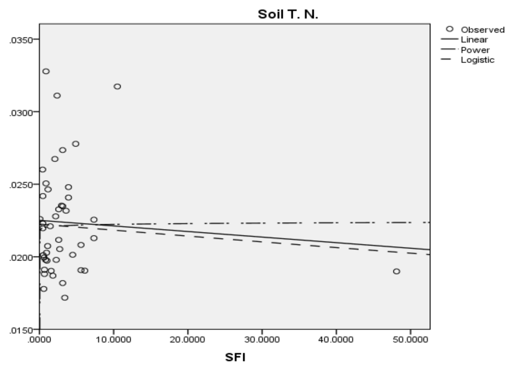


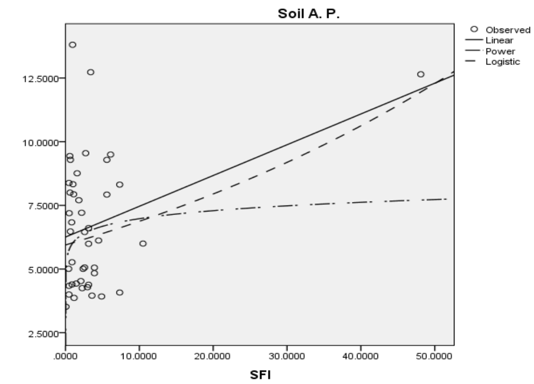
.489**	.240	.221	.855	.275**	.075	.053	7.730
The dependent variable is ln($CaCO_3$).				The dependent variable is ln(OM).			



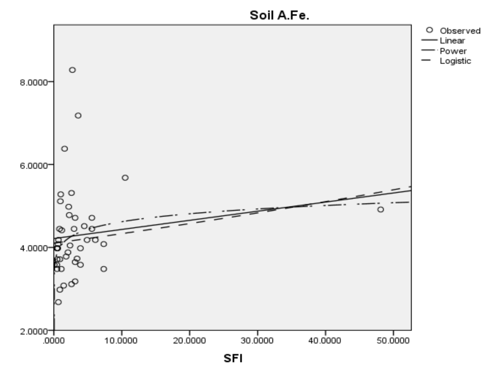


.088*	.008	-.016-	.157	.199*	.040	.017	.360
The dependent variable is ln(Total N).				The dependent variable is ln(Available P).			





.30**	.090	.068	.215	.453**	.205	.186	.418
The dependent variable is ln(available Fe).				The dependent variable is ln(available Mn).			



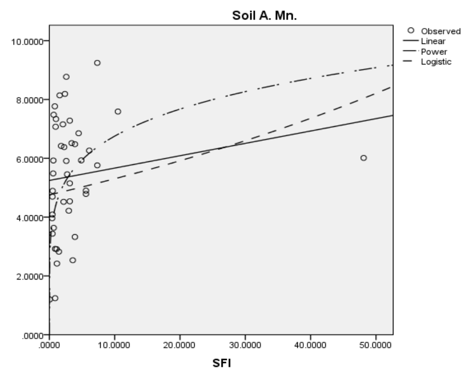
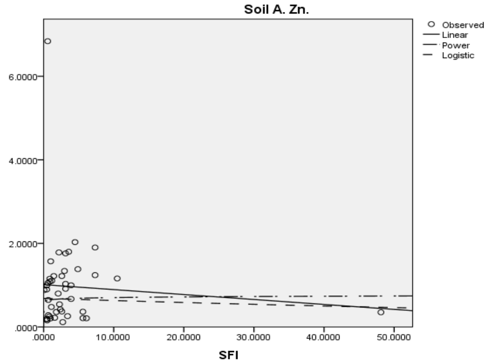
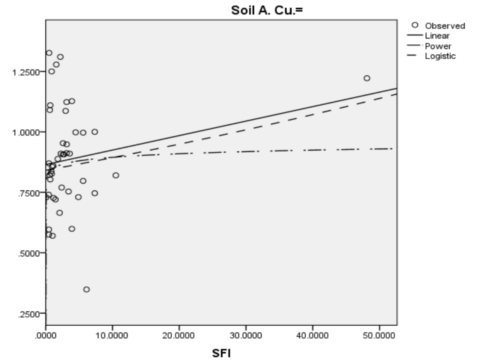
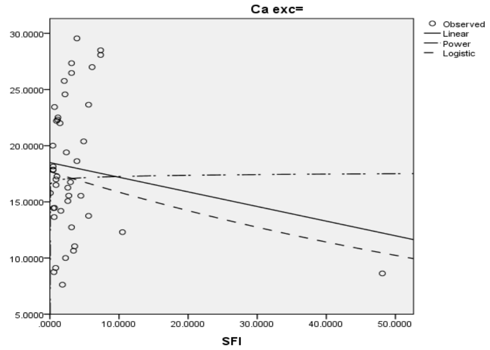


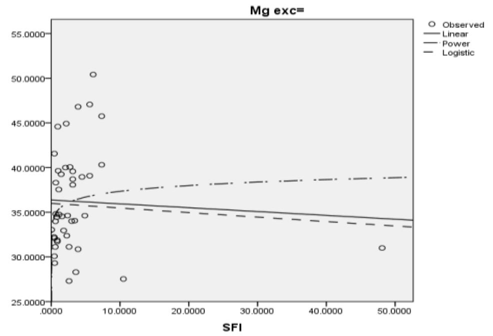
Table 8. Cont.

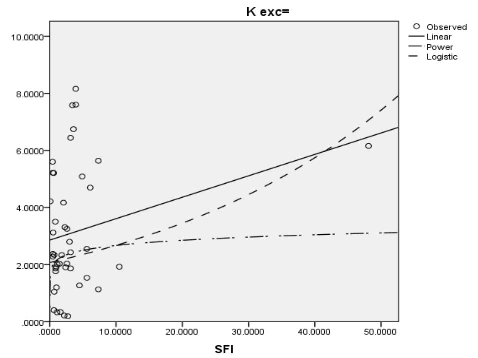
Model Summary							
R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
.043	.002	-.022-	.895	.104*	.011	-.013-	.261
The dependent variable is ln(available Zn).				The dependent variable is ln(available Cu).			
.028	.001	-.023-	.358	.188*	.035	.012	.150
The dependent variable is ln(exchangeable Ca).				The dependent variable is ln(exchangeable Mg).			
.115*	.013	-.010-	.939	.202**	.012	.177	.881
The dependent variable is ln(exchangeable K).				The dependent variable is ln(exchangeable Na).			

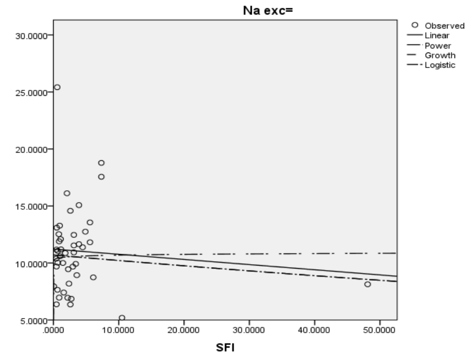












REFERENCES

Abdel Rahman, M.; Metwaly, M. and Shalaby, A. (2019). Quantitative assessment of soil saline degradation using remote sensing indices in Siwa Oasis. Journal Article In AGRIS since: 2019 Volume: 13 Issue: 4 Extent: 53-60 Publisher: Elsevier B.V. http://www.nal.usda.gov/

Abdul Ghafar, M. S. (2014). Desertification and its impact on agriculture production in Siwa Oasis. Middle East Journal of Agriculture Research, 3 (2): 155-166,

Abou Kota, M. (2012). Distribution of salinity and nutrients in soils of Egypt and Tunisia under recently environmental changes. M. Sc. Thesis. Institute of African Research and Studies. Cairo Univ. Egypt.

Abou Kota, M. (2016). Spatial modeling and prediction of soil salinity using SALTMED in A GIS environment in Egypt and Ethiopia. Ph. D. Thesis. Institute of African Research and Studies. Cairo Univ. Egypt.

Al-Baraznji, A. F. (1973). Gypsioferous soils in Iraq. Ph. D. Dissertation. Ghent university. Belgium.

Aldabaa, A. A.; Weindorf, D. C.; Chakraborty, S.; Sharma, A. and Li, B. (2015). Combination of proximal and remote sensing methods for rapid soil salinity quantification. Geoderma, 239, 34- 46.

Anonymous, A. (1992). Procedures for collecting soil samples and methods of analysis for soil survey. Soil surv. Invest. Rep. 1 US Gov. Print Office, Washington DC.

Boruvka, L.; Vacek, O, and Jehlicka, J. (2005). Principal component analysis as a tool to indicate the origin of potentiality toxic elements in soils. Geoderma, 128: 289-300.

FAO, (1990). Management of gypsiferous soils. Food Agricultural Organization of United Nation. Rome. http:fao.org/docrep/to 323e/ro323e03.htm.

Ganzour, Sh. K. (2015). Application of geographic information system for management of some soil nutrients. Ph. D. Thesis. Faculty of Agriculture, Fayoum University. Egypt.

Hakima, O.; Mohamed, El.; Ahmed, B.; Mohamed, A.; Widad, E.; Lalla, A. and Mohamed, A. (2019). Multivariate statistical analysis for spatial evaluation of physicochemical properties of agricultural soils from Beni-Amir irrigated perimeter, Tadla plain, Morocco. Geology, Ecology And Landscapes, 2019, Vol. 3, No. 2, 83-94. https://doi.org/10.1080/ 24749508/2018.1504272

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results. What do the numbers mean? CSIRO Publishing, Melbourne.

Rashed, S. A. (2016). Evaluation of sustainable land management on some selected soils of Siwa oasis. Egypt. J. Soil Science. Vol.56, No.3, pp. 453-470.

Hedia, R. M. and Abd Elkawy, O. R. (2016). Assessment of Land Suitability for Agriculture in the Southeastern Sector of Siwa Oasis". Alexandria Science Exchange Journal, Vol. 37, No.4, pp 771 – 780.

Imoke, Eni. (2012). Effects of Land Degradation on Soil Fertility: A Case Study of Calabar South, Nigeria. Chapter (2), Page (21:34).

Jackson, M. (1973). Soil chemical analysis. Pretice- Hall, Inc., Englewood Cliffs, New Jersey, U.S.A.

Lindsay, W. and Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. J. Soil Sci. Soc. Amer., 42: 421-428.

London, J. (1991). Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Jone Wiley & Sons. Inc. New York, USA. 530p.

Mulugeta, T.; Asmare, M. and Wondwosen, T. (2019). Effects of land use types on selected soil physical and chemical properties: the case of Kuyu district, Ethiopia. Eurasian J. Soil Sci. 2019, 8 (2) 94-149.

Mustafa, S. and Orhan, D. (2014). Distribution and evaluation of soil fertility based on geostatistical approach in Bafra Deltaic plain. TÜrkiye Tarimsal Araştirmalar Dergisi- Turkish J. of Agricultural Research. 1(2): 186-195.

Olsen, S.; Cole, C.; Watanable, F. and Dean. L. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dept. Agric. Circular No. 939.

Page, A.; Miller, R. and Keeney, D. (1982). Methods of soil analysis. Part 2. Chemical and Microbiological Properties. 2nd (Ed.). Amer. Soc. of Agronomy. Madison, Wisconsin, USA.

Soltanpour, P. N. and Schwab, A. P. (1977). Soil test for simultaneous extraction of macro and micro nutrients in alkaline soils. Soil Sci, and plant Anal., 8:195-207.

SPSS (2015). Command syntax reference. Chicago. Illinois: SPSS 20.0 Inc. 2015.

Taher, M. H. (2017). Change Detection of Land Cover and Salt Affected Soils at Siwa Oasis, Egypt. Alexandria Science Exchange Journal, Vol. 38, No.3. July-September 2017 4, 2017, Accepted August 15, 2017.

USDA (2004). Soil laboratory methods, Soil Survey Investigation. Report No. 42 version 4.0 November 2004.

Wolf, B. (1971). The determination of Boron in soil extracts, Plant materials, composts, manures, water and nutrient solutions. Soil Science and Plant Analysis, 2: 363-374.

أليات الترابط بين تدهور خصوبة الآراضي والخواص الفيزوكيميائية في أراضي واحة سيوة

محمود سليمان محمد*، شيماء كمال جنزور و محمد السيد ابوقوطه

معهد بحوث الآراضي والمياه والبيئة – مركز البحوث الزراعية

تعد تقييمات تدهور خصوبة التربة مؤخرا بمثابة دليل على التحديات التنموية الخطيرة التي تواجهها العديد من المناطق الزراعية في مصر. وبالتالي، فإن السياسات الزراعية التي تسهم في استخدام التكنولوجيا الزراعية المحسنة والممارسات الأكثر كفاءة لاستخدام المياه ستوفر المياه التي يمكن استخدامها في أي مكان آخر. مع تزايد الطلب على الغذاء وارتفاع درجة عدم اليقين بشأن التأثير المستقبلي للتغيرات البيئية، سيصبح الاستخدام الفعال للمياه أو تقييم التربة أكثر أهمية بالنسبة للمناطق في السنوات القادمة. أظهرت الخصائص الرئيسية للتربة التي تمت دراستها أن أعلى تركيز للأيونات في مستخلص عجينة التربة هو الصوديم والكلوريد. يمكن تصنيف درجة الحموضة في التربة على أنها قلوية قليلاً إلى قلوية معتدلة. التربة القلوية ، التي تحتوي على ESP أكثر من 15٪. بشكل عام، كانت معظم التربة طمية نسبيا. من ناحية أخرى، كانت بعض الملامح الرملية والرملية الطينية الطميية والرمل الطميية والرمل. كشف تحليل نتائج التباين أن CEC للتربة في منطقة الدراسة كان بين 3.16 إلى 24.96 Cmolc kg^{-1}. كشف تحليل نتائج التباين أن محتويات المادة العضوية في التربة كانت منخفضة؛ أظهرت النتائج أن القيم تتراوح بين 0 إلى 4.98٪. بناءً على تصنيف $CaCO_3$، تميزت منطقة الدراسة بنسبة عالية من $CaCO_3$ في معظم دراسات التربة، مما يشير إلى وجود تربة جيرية. اعتبرت منطقة الدراسة خفيفة للغاية؛ بعض الشيء؛ معتدلة وعالية بمحتواها من الجبس. أشارت البيانات إلى أن المغذيات الميسرة في منطقة الدراسة منخفضة. أشار تحليل نتائج التباين إلى أن الكاتيونات المتبادلة تأثرت بشكل كبير بالتغيرات البيئية التي حدثت مؤخرًا. كانت قيم Ca المتبادل بين 7.62 إلى 29.55 Cmolc kg^{-1} بمتوسط قيمة قدره 17.87 Cmolc kg^{-1}، وتراوحت Mg المتبادل ما بين 27.31 إلى 50.41 Cmolc kg^{-1} و 34.74 Cmolc kg^{-1} في المتوسط تراوحت بين 5.19 و 25.41 cmolc kg^{-1} بمتوسط قيمة 17.87 Cmolc kg^{-1} و K المتبادل بين 0.19 إلى 8.16 Cmolc kg^{-1} و 2.8 Cmolc kg^{-1} في المتوسط. اجريت هذه الدراسة لدراسة التباين المكاني لخصائص مثل درجة الحموضة للتربة ، درجة التوصيل الكهربي، محتوي التربة من كالسيوم كربونات، محتوي التربة من المادة العضوية، النتروجين الكلي، الفسفور الميسر، المنجنيز الميسر، النحاس الميسر، الكالسيوم المتبادل، الصوديم المتبادل، البوتاسيوم المتبادل. بالإضافة إلى ذلك استخدام مؤشر خصوبة التربة "عالية التقنية". ويعد التقييم الكمي ل SFI بإستخدام التغير المكاني لبيانات التربة وتقنيات النمذجة عملية مهمة للغاية. SFI في منطقة دراستنا هي خصوبة منخفضة للغاية (20> = S4) وفقًا لفئات وقيم مؤشر خصوبة التربة. كما تم حساب معامل ارتباط بيرسون لتحديد الارتباط الإيجابي الهام بين SFI و (درجة الحموضة للتربة، درجة التوصيل الكهربي، ومحتوي التربة من كالسيوم كربونات، محتوي التربة من المادة العضوية ، النتروجين الكلي، الفسفور الميسر، المنجنيز الميسر، النحاس الميسر، الكالسيوم المتبادل، الصوديم المتبادل، البوتاسيوم المتبادل). بالإضافة إلى ذلك ، أشار معامل الارتباط إلى أن SFI يرتبط بشكل غير مهم وإيجابي بالزنك الميسر والمغنيسيوم المتبادل.