Contribuations of Remote Sencing and Giographic Information Systems in Sustainable Agricultural Development

a. Developing Soil Fertility Maps of Farafra Oasis Using Remote Sensing and GIS Techniquesto Manipulate and Produce Fertility Maps

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ABSTRACT

Geographic Information Systems (GIS) constitutes an efficient and versatile tool to manipulate and produce-fertility maps. Status of some soil fertility indicators are importance for sustainable agricultural development. Some macro and micronutrients, salinity and soil organic matter are studied. Soil fertility variables in the study area were assessed using GIS techniques. WhereasArc View GIS system is used to perform the soil fertility maps. One hundred and sixsurface layers samples representative (0-30 cm) in area of Farafra Oasis areinvestigated producesoil maps of elements of fertility status. The obtained results from data and fertility maps could be summarized as follows: - Electrical conductivity Percentages were 17.5, 53.8, 19.9 and 8.8 % represented low, medium, high and very high amounts respectively, electrical conductivity values ranged from 1.3 to 89.4 dSm⁻¹.- All the studied surface layers are considered low level for organic matter content, Pand Zn.- Total inorganic nitrogen (TIN) were 75 and 25 % represented low and medium classes respectively, and values ranged from 9 to 375µg g⁻¹.- Levels of K were 60 and40 %, represented low and medium classes respectively.- Available B content in the studied soil profiles range from 0.5 to 22.5µg g⁻¹with an average 3.1-µg g⁻¹.- Available Fe percentages were 3.7, 62.6 and 33.7% represented low, marginal and sufficient values, respectively.- About 100 % of Zn total area represent 3493.2faddan is considered high level. - The critical values of the surface layers reached to 25 % Cu. - The statistical analysis of the simple correlation coefficients between macro-micronutrients and some propertied of soils.

Keywords: Soil fertility, GIS, micronutrients and Farafra Oasis

INTRODUCTION

Maps are fundamental to site-specific soil fertility management (SSFM) because they represent either the spatial state of a condition of interest, the prescription of inputs needed to manage a particular condition site-specifically, or a record of inputs or outputs. Pierce and Nowak, (1999).

Modern information technology that link geographic information system (GIS) capabilities with remote sensing (RS) data contribute significantly to the assessment and management of the planned agricultural development Zhou *et. al.*(1989) and Davis *et.al*(1991). Geographic Information Systems (GIS) benefit land use planning and precision agriculture practices. It constitutes an efficient and versatile tool to manipulate and produce soil fertility maps.

related limitations affecting Soil productivity include nutritional disorders, and can be detected by evaluating the fertility status of the soil. Micronutrient cycling is quite different among various terrestrial ecosystems (Han et. al., 2007). Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils that have a high degree of spatial variability. Soil properties that can be changed in a short time by land use are dynamic soil quality indicators (Chanet. al., 2001). Adesanwoet. al., (2009) reported that management of soil fertility is the first condition for sustainable crop production and can reduce food importation in many countries. The current study aimed to identify soil fertility status using the integration of GIS techniques of the studied area at south Farafra Oasis for sustainable agriculture development,

MATERIALS AND METHODS

Location

The studied area is located south of Farafra city. Its bundled by six coordinate points illustrated as

follows: point 1 :N 26 29 746 E27 43 415, point 2: N 26 29 741 E27 44 794, point 3: N 26 26 486 E27 42 692, point 4: N 26 26 559, E27 41 446, point 5: N 26 28 285 E27 41 347 and point 6: N 26 28 280 E27 42 44 Fig. (1). The studied area covers approximately 3430feddan (≈1372 ha).

Soil sampling and analysis

One hundredand six surface soil samples (0-30 cm) were collected from different sites at south of Farafra Oasis (Fig. 1). The samples were air-dried, ground in a wooden mortar and passed through 2 mm sieve. Proportion of this 2 mm sieved-soil was finely ground to pass 1 mm sieve for trace elements analysis.

The amounts of -soil micronutrients are obtained by extracting with DTPA-reagent according to Lindsay &Norvell(1978) and its concentration is measured by Perkin Elmer atomic absorption spectrophotometer, others chemical and physical analyses are carried out according to Page *et. al.*,(1982).

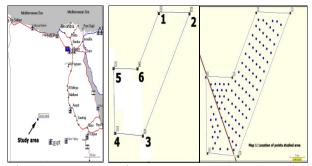


Fig. 1. Location of the study area, boundaries' coordinates and profiles sites.

Descriptive statistical analysis

The data analyses are carried out using descriptive statistical parameters (minimum, maximum, mean, median, standard deviation, and variance) and are calculated for the different variables by SPSS software (2003).

Building up digital georeference database

Data input process is the operation of entering the spatial and non-spatial data into GIS using ArcView

software ESRI (1999). Each soil observation is georeferenced using the Global Position Systems (GPS) and digitized, (Table1).

Table 1. Latitudes longitudes and elevation points of the studied surface layers

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	53	N26 27.822	E27 42.726	152		N26 27.058	E27 41.948	151

The different soil attributes are coded, and new fields are added to the profile database file in Arc view software. Soil fertility maps are done for soil salinity, soil organic matter. Nitrogen, Phosphorus, Potassium, Iron, Manganese, Zinc, Cu and Boron using module Arc Scripts in ArcView 9.3.

To produce fertility maps, the value of each soil characters is classified into three levels (low, medium and high), except EC values 4 levels are reported according to literature by several authors. The critical levels for different element are summarized in Table 2 and Fig. 2.

Table 2	Critical limit	s of the studied	l items and the	ir percentages.

Item	Level	Critical limit	M^2	KM^2	Fadden	Hectare	%
	Low	<4	2515362	2.52	598.90	249.5	17.5
	Medium	48	7745543	7.75	1844.18	768.4	53.8
EC	High	816	2869951	2.87	683.32	284.7	19.9
	VH	>16	1274303	1.27	303.41	126.4	8.8
	Total		14405159	14.41	3429.80	1429.1	100.0
	Low	<1.7	14405159	14.41	3429.80	1429.1	100.0
OM	Medium	1.7-2.6	0.00	0.0	0.0	0.0	0.0
OM	High	>2.6	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	<1.7	10814950	10.8	2575.0	1072.9	75
TNI	Medium	1.7-2.6	3590209	3.6	854.8	356.2	25
IN	High	>2.6	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	<5	14405159	14.4	3429.8	1429.1	100.0
D	Medium	510	0.00	0.0	0.0	0.0	0.0
P	High	>10	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low		8521206	8.5	2028.9	845.4	60
17	Medium	<85	5883953	5.9	1400.9	583.7	40
K	High	85-170	0.00	0.0	0.0	0.0	0.0
	Total	>170	14405159	14.4	3429.8	1429.1	100.0
	Low	<1	956650	1.0	227.8	94.9	6.6
В	Medium	15	10896210	10.9	2594.3	1081.0	75.6
В	High	>5	2552299	2.6	607.7	253.2	17.7
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	<2.5	531883	0.5	126.6	52.8	3.7
E-	Medium	2.5-4.5	9163897	9.2	2181.9	909.1	63.6
Fe	High	>4.5	4709379	4.7	1121.3	467.2	32.7
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	<1	14405159	14.4	3429.8	1429.1	100.0
M.,	Medium	12	0.00	0.0	0.0	0.0	0.0
Mn	High	>2	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	< 0.5	14086030	14.1	3367	1402	98.2
7	Medium	0.5-1	319129	0.3	61.8	148	1.8
Zn	High	>1	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0
	Low	< 0.2	3568047	3.6	849.5	354.0	24.8
C	Medium	0.2-0.4	10837112	10.8	2580.3	1075.1	75.2
Cu	High	>0.4	0.00	0.0	0.0	0.0	0.0
	Total		14405159	14.4	3429.8	1429.1	100.0

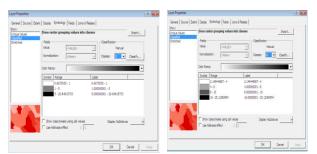


Fig. 2. Classify of the studied items to three and four classes

RESULTS AND DISCUSSION

Fertility maps of salinity and organic matter Salinity status(EC)

Area distribution according to Electrical conductivity (EC) levels is as follows, about 600faddan (17.5%) of the total area is nonsaline, 1844 faddan (53.8%) is moderate saline, 684 faddan (19.9%) high saline and 303 faddan (8.8%) very high saline Fig 3 and Table 2. EC Values of the investigated surface layers varied from 1.3 to 89.4 dS/m with an average 7.3 dS/m Table 3. The minimum value is recorded in location No. 53 while the maximum value is shown in site No. 82. Both of two sites are having medium texture (sandy clay

loam). The literature index values of salinity are < 4, 4-8, 8-16 and > 16 dS/m representing low, medium, high and very high, respectively, these values reported by Rechards (1954). The EC value lower than 4 dS/m is considered a limit of nonsaline soil. Electrical conductivity (EC) has positive correlations with CEC (r=0.806), organic matter (r=0.618)\forall K (r=0.876). Mg (r=0.848) and B (r=0.725). Table 4.

Organic matter status (OM)

Percentages of OM, in the surface samples of the studied area are lowerthan (<1.7 %) OM (Fig.3). Values of organic matter percentages varied from 0.05 to 1.35 %with an average 0.34 % Table 3.

The minimum value is recorded in location No, 47, while the maximum value is shown in site No, 90. Minimum and maximum values have coarse texture (sandy soil). The limits of OM are as follows< 1.7, 1.7-2.6 and > 2.6 % representing low, medium and high levels respectively reported by Richards (1954). Organic matter percentage has positive correlations with CEC (r=0.799), EC (r=0.618) and Cl (r=0.724), (Table 4).

Fertility maps of some macronutrients Nitrogen (N)

Inorganic Nitrogen content (NH $_4$ and NO3) in the studied soils varied from 9 to 375 μ g g $^{-1}$ with an average 29 μ g g $^{-1}$,(Table 3). The minimum value is detected in

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location No. 42 while the maximum is found in site No, 82. The limit values of N are < 40 low. 40-80 medium and > 80 $\mu g~g^{\text{-1}}.$

Regarding the soil fertility map of N, the areas and percentages are as follow, about 2575faddan (75%) of the total area is low and 855 faddan (25%) is moderate, Table 2 and Fig (3). The NO3 N form has positive correlations with EC (r=0.915), CEC (r=0.686) and Organic nitrogen ON (r=0.620),(Table 4).

Phosphorus (P)

Values of soil P varied from 1.8 to 6.1 μg g⁻¹ with an average 3.6 μg g⁻¹, Table (2). Both minimum and maximum values have coarse texture. The literature index values of soilP are < 5, 5-10 and > 10 μg g⁻¹, representing low, medium and high, respectively.As for soil fertility map of P,mostsamples are considered low value (Fig 3).

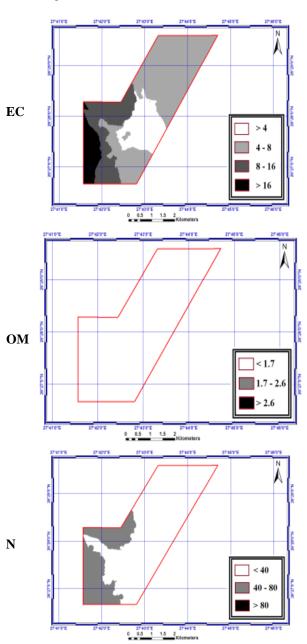


Fig. 3a. Soil fertility maps of some variables in the study area

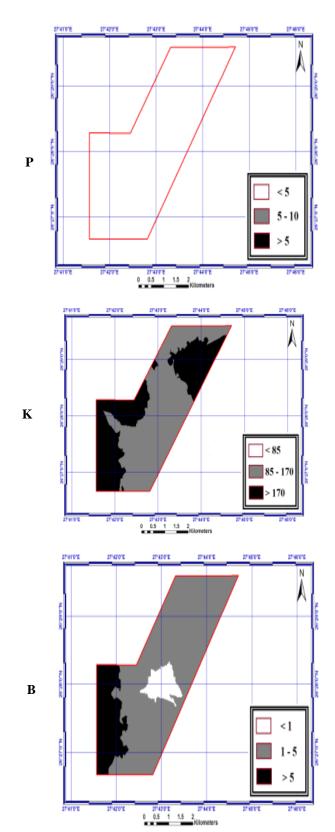


Fig. 3b. Soil fertility maps of some variables in the study area

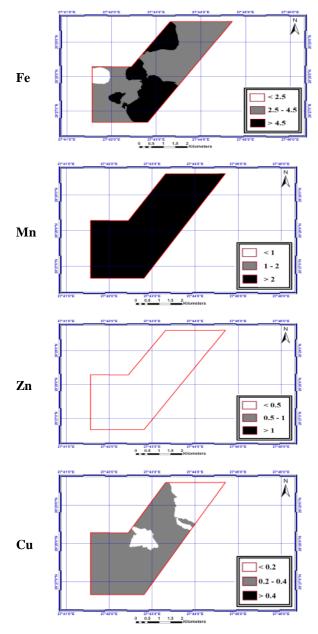


Fig. 3c. Soil fertility maps of some variables in the study area

Fertility maps of some micronutrients Boron (B)

Data in Table 3 reveal that available B content in the studied soil samples range from 0.5 to 22.5 μ g g⁻¹, with an average 3.0 μ g g⁻¹. The lowest value is found in location No. 24, which is coarse textured i.e., sandy soil. On the other hand, the highest value is in site No. 75 that has fine texture, namely clay soil.

The index values of boron extracted from soils are <1.0, 1.0-5.0 and > 5.0 μ g g⁻¹representing unsufficient, sufficient and toxic, respectively, reported by Reisenaueret. al.,(19.73). About 6.6 % of the samples under investigation contain unsufficient concentration of available boron, while 75.6 % are sufficient and 17.7 % have toxic limits of extractable B. The high content of boron is found in medium and fine textured soils (sandy clay loam, clay loam and clay) which is associated with high soil pH.Katyalet. al.(1983) mentioned that arid soils show exceptionally high B values but their availability decreases with soil coarse texture and low organic matter. These results are in harmony with Khalil (2014). For fertility map. Fig 3 show three levels of B (low, medium and high) and percentages of their areas. The corresponding areas of these are 227.8, 2594.3 and 607.7 faddan respectively, Table (2).

Values of available B have positive and significant correlations with organic N (r=0.768), salinity (r=0.725), K (r=0.742) and CEC (r=0.779), Table (4).

Iron (Fe)

Table 3 reveals that Fe content ranges between 1.7 and 8.4 μg g-1 with an average 4.2 μg g⁻¹. Also, the coarse texture has lower values in location No. 88. The highest value is detected in the heavy textured soil of site No. 75.

Values of Fe extracted from soils are classified as low (<2.5 μg g⁻¹), marginal (2.5-4.5 μg g⁻¹andadequate (> 4.5 μg g⁻¹) ,according to lindsay and Norvell (1978). Samples under investigation contain about 3.7 % within critical level of available iron, 63.6 % in marginal level and 32.7 % at adequate available iron Table 2 and Fig. 3.

	Table 4	. Correlations	between differen	t variables of the	e studied soil samples.
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Items	pН	EC	CEC	Lime	OM	ON	NH ₄	NO ₃	P	K	Zn	Fe	Mn	Cu	В
EC	-0.5059	1.0000													
Cl	-0.4733	0.5835													
Na	-0.5567	0.8082													
CEC	-0.5927	0.8062	1.0000												
Lime	0.3785	-0.2068	-0.3117	1.0000											
OM	-0.4077	0.6183	0.7994	-0.3326	1.0000										
ON	-0.5384	0.6990	0.8144	-0.5151	0.7417	1.0000									
NH_4	-0.4141	0.3617	0.4647	-0.5529	0.3986	0.4675	1.0000								
NO_3	-0.4302	0.9153	0.6862	-0.1675	0.6081	0.6196	0.1915	1.0000							
P	-0.0411	0.1460	0.3270	0.4594	0.2903	0.0736	-0.4333	0.2127	1.0000						
K	-0.4068	0.8755	0.6939	-0.0026	0.5040	0.6078	0.2584	0.7776	0.2875	1.0000					
Zn	-0.2762	0.4652	0.5084	-0.1858	0.6503	0.5722	0.1985	0.5842	0.2151	0.3178	1.0000				
Fe	0.1797	0.0265	0.0676	0.3258	0.0182	0.0059	-0.3858	0.1270	0.5930	0.0378	0.2521	1.0000			
Mn	0.1577	0.0221	0.0864	0.1957	0.3717	0.0487	-0.1965	0.1761	0.4945	-0.0961	0.5483	0.6294	1.0000		
Cu	-0.1258	0.4308	0.4444	-0.0848	0.6043	0.3509	0.3058	0.4637	0.1811	0.3759	0.6289	0.1216	0.4237	1.0000	
В	-0.3617	0.7252	0.7793	-0.1372	0.5389	0.7678	0.3531	0.6093	0.1706	0.7422	0.4364	0.0322	-0.0732	0.4622	1.0000

These results are in harmony with Abdel Razik (1999) who stated that available Fe extracted by DTPA ranged from 0.3 to $24 \mu g g^{-1}$ in some soils of Egypt.

The obtained results reveal that statistical relationship as a simple correlation coefficient between

DTPA-exactable Fe and P content is positive correlation (r = 0.593), (Table 4).

Figure 3 show fertility map of Fe, represents 204.7 faddan of low level, 3405faddanof marginal level and 327.0faddanofadequate level.

Table 3. Main statistical parameters of the studied soil samples

Items	Minimum	Maximum	Mean	Sum	Range	Median	Standard Error	Standard Deviation	Kurtosis	Skewness
pН	6.6	8.9	8.22	796.95	2.3	8.2	0.04	0.35	3.34	1
EC	1.3	89.4	7.3	708.4	88.1	4.5	1.17	11.52	32.74	5.27
Cl	80	999.1	336.5	32641	919.1	180.9	36.36	358.07	1.1	1.23
Na	0.4	29.6	2.15	208.3	29.2	1.1	0.34	3.32	49.5	6.33
CEC	7.1	65.8	16.13	1565	58.7	11.5	0.99	9.74	8.02	2.53
Lime	0.8	7.1	4.35	421.5	6.3	5.2	0.18	1.74	-0.74	-0.76
OM	0.2	1.35	0.34	33.08	1.5	0.27	0.03	0.32	0.79	1.05
ON	13.2	50	20.85	2022.4	36.8	19.9	0.74	7.32	1.79	1.27
NH_4	1.5	8	2.81	272.2	6.5	2.4	0.12	1.18	3.16	1.57
NO_3	7.5	367	26.25	2545.8	359.5	10	4.7	46.25	31.47	4.95
P	1.8	6.1	3.6	348.8	4.3	3.85	0.08	0.81	0.91	1
K	45	885	164.7	15978	840	122	11.05	108.79	20.59	3.67
Ca	5.5	31	12.02	1166	25.5	8.5	0.66	6.52	1.67	1.68
Mg	0.2	6.5	1.16	112.8	6.3	0.85	0.1	1.03	11.41	3.02
SO_4	8	999.1	269.9	26182	991.1	105	36.79	362.34	0.21	1.35
Zn	0.1	0.9	0.24	23.4	0.9	0.2	0.02	0.19	2.18	1.4
Fe	1.7	8.4	4.24	411.1	6.7	4.5	0.12	1.15	2.64	0.49
Mn	1.8	2.75	2.24	217.4	0.95	2.2	0.02	0.19	1.1	0.48
Cu	0.1	0.6	0.23	22.3	0.65	0.2	0.01	0.15	0.53	0.76
В	0.5	22.5	3.13	303.95	22	1.1	0.42	4.18	9.69	2.9

Manganese (Mn)

The available manganese varied from 1.8 to 2.7 µg g⁻¹ with an average 2.2 µg g⁻¹. The minimum value is recorded in surface sample of location No. 12 which contains 7% calcium carbonate. This result is in agreement with Katyal *et.al.*(1983) and Murphy et. al. (1972). They mentioned that calcareous soils have high amounts of total Mn but available Mn is low. The maximum value of available Mn is found in site No. 75.

Considering 1.0 and 2.0 μg g⁻¹as critical limit and marginal range for Mn deficiency, according to Lindsay and Norvell, (1978), all the values of soil Mn in the surface layers are considered sufficient. Similar results are reported by Abdel Razik (1999) and Khalil (2014). who stated that available Mn extracted by DTPA varied from 0.8 to 30 μg g⁻¹. Available Mn has positive correlations with soil Fe (r=0.629). As for soil fertility map of Mn, the areas percentages of Mn levels are 488 faddan for marginal level, 3448 faddan for sufficient level (Fig 3).

Zinc (Zn)

Data in Table 3 show available Zn content in the studied soil samples ranged from 0.05 to 0.9 μ g g⁻¹with an average 0.24 μ g g⁻¹. According to Lindsay and Nowell, (1978), the index values for Zn extracted from soils by DTPA are Low (<0.5 μ g g⁻¹, marginal (0.5-1 μ g g⁻¹) and adequate (> 1 μ g g⁻¹). The surface layers in the studied soils contain 98.2 % as low and 1.8 % adequate. All values of available Zn in the studied surface layers are considered not sufficient for plants. The maximum values (0.8, 0.9 and 0.9 μ g g⁻¹) are found in soils which have medium and fine texture i.e. sandy clay loam, clay

loam and clayey soils respectively. These results are in harmony with Khalil (2014)

The total area of soil fertility map for Zn is 3430Faddan, include 3386faddanlow Zn level and 61.7faddan marginal Zn level. Fig. (3).The obtained values of simple coefficients indicate positive significant correlation between available Zn and OM (r=0.650).

Copper (Cu)

The critical values of Cu in the studied surface layers reached 61.8 %. The obtained values of DTPA-extractable Cu in Table 3 reveal that available Cu content varied from 0.05 to 0.6 μ g g⁻¹, with an average 0.2 μ g g⁻¹. According to Lindsay and Norvell, (1978), the index value used for Cu extracted from soils by DTPA method are critical (<0.2 μ g g⁻¹), marginal (0.2-0.4 μ g g⁻¹) and high (> 0.4 μ g g⁻¹).

Soil fertility map for Cu, Fig 3 show levels of Cu (low and medium). The corresponding areas of these levels are 3.6, and 10.8 km² respectively. These results are in harmony with Khalil (2014).

The obtained values of simple coefficients indicate positive significant correlation between available Cu and both of OM (r=0.604) and Zn (R=0.629).

CONCLUSION

The agricultural management practices e.g. leaching requirements for salt soils, fertigation, addition of organic matter, cropping patterns and precision agriculture improving nutritive elements status and crop production under investigation area.

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انتاج خرائط خصوبة التربة باستخدام تكنيك GIS لبعض أراضي واحة الفرافرة ـ مصر إبراهيم محمد عبد العزيز حجازي معهد بحوث الأراضي والمياه والبينة _ مركز البحوث الزراعية _جيزة _مصر

يهدف البحث إلى إنتاج خرائط خصوبة التربة باستخدام تكنيك نظم المعلومات الجغرافية SIGe دراسة ملوحة التربة والمادة العضوية وبعض العناصر المغذية الصغرى والكبرى مثل النتروجين والفوسفور والبوتاسيوم والحديد والمنجنيز والزنك والنحاس والبورون في بعض أراضى منطقة واحة الفرافرة، ومدى تأثير هذه العناصر ببعض خواص الأرض موضع الدراسة. ولتحقيق ذلك تم اختيار 106عينة تربة سطحية تمثل اراضي منطقة الدراسة، وكانت النتائج المتحصل عليها كالتالى: - أظهرت خرائط التربة أن قيم نسب التوصيل الكهربائي كانت كالأتي : - منخفضة بنسبة 17.5% ، متوسطة بنسبة 53.8% ، مرتفعة بنسبة 19.9% ، مرتفعة بنسبة 19.9% ، متوسط 13.3 ميكروجرام/جرام - كانت قيم كل من الماده وقد تراوحت قيم ملوحة التربة من 13.3 حتي 89.4 ميكروجرام/جرام بمتوسط 73 ميكروجرام/جرام - كانت قيم كل من الماده العضوية والفوسفور والزنك ذات محتوي منخفض وذلك في منطقة الدراسة. نسبة النيتروجين المعدني (الامونيا و النترات) كانت 75 مرام . كانت مستويات عنصر البوتاسيوم في المنطقة المدروسة منخفضة وهامشية وتمثل النسب 60% , 40% مع التوالي . تراوحت قيم عنصر البورن من 5. إلي 22.5 ميكرو جرام / جرام متوسط 1.3 ميكرو جرام / جرام . كانت نسب عنصر الحديد 13.7 ، 62.6 ميكرو حرام / جرام مرتفع. حواص التوالي . كل المساحة المدروسة لعنصر الزنك احتوت علي قيم ذات مستوي مرتفع. - احتوت قيم عنصر النحاس علي نسبة 52% من إجمالي منطقة الدراسة وتمثل الحد الحرج للعنصر. - أظهر قيم ذات مستوي موجود علاقة قوية بين العناصر المدروسة وبعض خواص التربة، فضلاً عن وجود ارتباط بين بعض العناصر وبعضها.