RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1. Soil profile description and brief features of soils of the 8 regions:

The studied soils represent eight regions; of (from west to east): El-Maraqui, Khamisa, Siwa, Aghormi, Qureishet, Abu-Shrouf, El-Shrouf, El-Zeitun and Timeira El-Masser. Descriptions of the 19 soil profiles of the area are presented in **Appendix I**.

4.1.1. Soils of the El-Maraqui region:

These soils are represented by profiles 1 and 2. The soils are sandy loam to heavy clay in texture and are slightly to strongly calcareous.

This region borders the Oasis from the west at about 30 km from Siwa town. It has many olive, alfalfa, tomato and date palm grove orchards that get their irrigation water from springs and shallow wells as well as from a newly dug deep well (Baid El-Deen well).

4.1.2. Soils of the Khamisa region:

These soils are represented by profiles 3, 4 and 5. The soils are loamy sand to silty clay in texture and are slightly to moderately calcareous. This region lies 12 km west of Siwa town. It has many springs and shallow wells which provide irrigation water to numerous orchards planted with fruit trees such as apples, nabk, grapes trees lemon, date palm trees and olive trees.

4.1.3. Soils of the Siwa region:

These soils are represented by profiles 6 and 7. The soils are sandy loam to light clay in texture and are strongly calcareous. This region lies between Khamisa and Aghormi regions. It has palm and olive orchards getting their water from springs.

4.1.4. Soils of the Aghormi region:

These soils are represented by profiles 8, 9, 10 and 11. The soils are sand to heavy clay in texture and are strongly to extremely calcareous. This region is located 3 km east of Siwa town, where the remains of Amoun Temple are found.

4.1.5. Soils of the Qureishet region:

These soils are represented by profiles 12 and 13. The soils are sandy loam to sandy clay loam in texture and are with 2.8 to 25.6 % $CaCO_3$. This region is located to the west of Abu Shrouf region about 22 km east of Siwa town adjacent to road leading to El-Zeitun.

4.1.6. Soils of the Abu-Shrouf region:

These soils are represented by profiles 14 and 15. The soils are sandy loam to light clay in texture and are strongly calcareous. This region lies west to El-Zeitun region 30 km from Siwa town.

4.1.7. Soils of the El-Zeitun region:

These soils are represented by profiles 16 and 17. The soils are clay loam to light clay in texture and are extremely to strongly calcareous. This region lies between Abu-Shrouf and Timeira El-Masser region. It has located at about 35 km east of Siwa town and on the eastern bank of El-Zeitun Great Lake.

4.1.8. Soils of the Timeira region:

These soils are represented by profiles 18 and 19. The soils are loamy to light clay in texture and are strongly calcareous. This region occupies a large portion of Saw Oasis. It lies between El-Zeitun region and the eastern border of Siwa oasis.

4.2. Calegorization of soil units:

Soil units were categorized using texture and soil depth.

4.2.1. Particle size distribution and texture (Table 7):

The data show the particle size distribution determined by two methods. The first method takes in account calcium carbonate of the soil, i.e., particle size distribution was determined without destruction of soil $CaCO_3$. The second method excludes the soil calcium carbonate, i.e., particle size distribution was determined after destruction of the calcium carbonate content of the soil.

Soils of the El- Maraqui region varied in their texture between sandy loam and heavy clay.

Soils of the Khamisa region varied in their texture between loamy sand and silty clay. Soils of the Siwa region varied between sandy loam and light clay. Soils of the Aghormi region varied texture between sandy and heavy clay.

Soils of the Qureishet region varied in their sandy loam and sandy clay loam. Soils of the Abu-Shrouf region varied between sandy loam and light clay. Soils of the El-Zeitun region varied between clay loam and light clay while soils of the Timeira El-Masser region varied between loamy and light clay.

Table 7: Particle size distribution and textural class *of Siwa soils; determined by 2 methods 1: without destruction of $CaCO_3$ ($CaCO_3$ included) , and 2 : after destruction of $CaCO_3$($CaCO_3$ excluded).

Region	Profile No.	Depth, (cm.)	Particle size distribution % and textural class									
			With CaCO3 included					With CaCO3 excluded				
			Coarse sand	Fine sand	Silt	Clay	Textural Class	Coarse sand	Fine sand	Silt	Clay	Textural Class
El-Maraqui	1	0-60	49.9	23.1	7.0	20.0	SCL	55.2	26.7	6.0	12.1	Sandy loam
		60-90	44.6	32.2	15.2	8.0	Sandy loam	49.6	28.8	13.2	8.4	Sandy loam
		90-150	53.23	22.03	2.34	22.4	SCL	55.4	25.8	1.6	17.2	SCL
	2	0-30	40.3	29.8	9.7	20.2	SCL	31.1	46.4	3.2	19.3	SCL
		30-60	12.0	32.0	15.0	41.0	Hv C	9.8	44.1	14.9	31.2	LtC
		60-90	5.6	29.1	20.9	44.4	Hv C	3.0	40.2	16.3	40.5	Hv C
		90-150	14.9	5.0	20.1	60.0	Hv C	9.6	6.4	17.4	66.6	Hv C
Khamisa	3	0-50	62.2	19.4	6.4	12.0	Sandy loam	67.7	21.2	3.3	7.8	LS
		50-90	6.0	14.0	50.0	30.0	Si C	5.4	15.8	47.7	31.1	Si C
	4	0-60	53.8	23.8	2.4	20.0	SCL	54.2	25.3	2.0	18.5	SCL
		60-90	53.7	21.1	6.4	18.8	SCL	58.1	22.7	3.4	15.8	SCL
		90-150	66.3	14.9	5.2	13.6	Sandy loam	69.3	13.1	4.4	13.2	Sandy loam
	5	0-40	30.8	24.2	15.0	30.0	Lt C	31.6	25.9	9.6	32.9	SC
		40-80	8.8	36.2	30.	25.0	CL	6.7	39.6	29.0	24.7	CL
		80-150	15.5	45.4	15.1	24.0	SCL	12.7	52.1	13.6	21.6	SCL
Siwa	6	0-30	25.6	26.3	25.0	23.1	CL	29.0	33.1	17.6	20.3	SCL
		30-60	9.6	20.2	40.2	30.0	Lt C	6.4	28.0	39.3	26.3	Lt C
		60-90	4.8	30.2	25.0	40.0	Lt C	3.7	38.6	18.2	39.5	Lt C
	7	0-55	49.9	17.3	18.0	14.8	Sandy loam	54.5	19.6	11.9	14.0	Sandy loam
		55-75	39.0	30.0	11.0	20.0	SCL	46.5	36.4	9.8	7.3	Sandy loam
		75-150	37.0	32.0	20.0	11.0	Sandy loam	45.1	37.5	9.9	7.5	Sandy loam
Aghormi	8	0-45	40.0	19.9	20.1	20.0	SCL	44.7	23.4	15.9	16.0	SCL
		45-85	17.9	17.0	40.0	25.1	CL	18.6	23.2	35.9	22.3	CL
		85-150	5.0	15.0	30.0	50.0	Hv C	6.8	16.1	39.3	37.8	Lt C
	9	0-45	21.3	11.7	22.0	45.0	Hv C	28.3	14.6	20.4	36.7	Lt C
		45-90	19.0	12.6	18.4	50.0	Hv C	16.9	16.0	14.1	53.0	Hv C
	10	0-50	88.9	7.3	3.2	0.6	S	91.3	7.3	1.3	0.1	S
		50-90	86.6	8.2	3.4	1.8	S	95.4	2.8	1.6	0.2	S
		90-150	89.3	7.5	3.0	0.2	S	98.3	0.4	1.2	0.1	S
	11	0-45	77.8	8.4	9.8	4.0	LS	82.8	6.9	6.8	3.5	LS
		45-95	85.2	12.0	1.8	1.0	S	94.7	3.9	0.9	0.5	S
		95-150	72.7	18.9	5.2	3.2	S	80.1	16.2	2.6	1.1	S

Table 7 Cont.

Region	Profile No.	Depth, (cm)	Particle size distribution % and textural class									
			With CaCO3 included					With CaCO3 excluded				
			Coarse sand	Fine sand	Silt	Clay	Textural Class	Coarse sand	Fine sand	Silt	Clay	Textural Class
Qureishet	12	0-45	60.3	13.1	21.0	5.6	Sandy loam	62.2	11.8	20.8	5.2	Sandy loam
		45-60	49.3	10.1	25.0	15.6	CL	54.6	11.5	18.9	15.0	SCL
		60-100	28.0	40.0	20.0	12.0	Sandy loam	30.8	40.4	17.4	11.4	Sandy loam
	13	0-45	62.8	20.0	10.0	7.2	Sandy loam	64.0	20.0	9.0	7.0	Sandy loam
		45-70	72.7	4.7	8.5	14.0	Sandy loam	72.9	3.8	8.5	14.8	Sandy loam
		70-150	52.1	25.0	12.0	10.9	Sandy loam	53.4	25.1	11.5	10.0	Sandy loam
Abu-shrouf	14	0-45	11.9	23.1	35.0	30.0	Lt C	10.1	22.6	35.4	31.9	Light C
		45-95	16.9	21.1	30.0	32.0	Lt C	12.1	28.3	29.6	30.0	Light C
		95-150	6.0	20.0	40.0	34.0	Light C	2.1	22.4	40.9	34.6	Light C
	15	0-45	45.9	23.1	20.1	10.9	Sandy loam	49.7	22.0	18.3	10.0	Sandy loam
		45-60	34.9	14.2	40.0	10.9	CL	36.2	13.5	39.1	11.2	CL
		60-100	26.4	19.6	38.0	16.0	L	29.9	18.5	35.2	16.4	CL
El-Zeitun	16	0-55	17.0	15.0	32.0	36.0	Lt C	18.1	16.6	30.3	35.0	Lt C
		55-90	12.0	20.0	31.1	36.9	Lt C	12.9	20.1	31.0	36.0	Lt C
		90-150	12.9	20.3	36.0	30.8	Lt C	14.1	18.4	37.5	30.0	CL
	17	0-55	13.1	27.0	39.0	20.9	CL	13.3	26.7	40.0	20.0	CL
		55-85	7.9	27.1	30.0	35.0	Lt C	8.9	29.3	40.3	21.5	CL
		85-150	6.4	18.6	34.0	41.0	Lt C	9.0	21.0	30.0	40.0	Lt C
Timeira	18	0-25	27.8	40.0	21.0	11.2	Sandy loam	25.4	40.5	23.1	11.0	Sandy loam
		25-50	29.4	14.6	44.4	11.6	Si L	30.6	14.3	44.1	11.0	Si L
	19	0-10	13.8	36.2	29.1	20.9	CL	15.3	40.4	24.3	20.0	CL
		10-40	19.0	30.0	40.0	11.0	L	14.9	30.2	44.5	10.4	L

*Texture is according to the International soil Texture triangle and not the American USDA Triangle (see appendex) since particl siz are done according to the International system and not the USDA system

S : sand; S L: Sandy loam; L S :Loamy sand; SCL :Sandy clay loam

Si L : Silty Loam; Si C : Silty clay; L : Loam ; C L : Clay loam Lt C: light clay; Hv C: heavy clay

4.2.2. Categorization of soil units on basis of soil depth and texture.

The soils of the study area were categorized into different units on basis of combinations of two soil characteristics soil depth and soil texture:

(A): Soil depth: Three designations are considered: 1- Deep: with profile depth of 150 cm or more. 2- Moderately deep: with depth of up to 90 to 100 cm. 3- Shallow: with depth of up to 40 to 50 cm.

(B): Soil texture: Three broad designations are considered, they are as follows, with texture classes nomenclature according to the International Soil Texture Triangle "or the FAO triangle" **(Farshad 1984):** 1-Coarse-textured i.e. "the sandy soils; these are the following 2 texture classes, sand, and loamy sand. 2- Medium-textured i.e. "the loamy soils". These are the following 6 texture classes: sandy loam, loam, sandy clay loam, clay loam, silt loam, and silty clay loam. 3-Fine- textured soil i.e. the clayey soils. These include the following 4 texture classes: heavy clay, light clay, silty clay and sandy clay.

Considerations were directed from the view point of the texture of the profile depth and /or upper and lower parts of it whenever a need arises. Eleven different units were recognized ranging from shallow to deep with regard to depth, and from coarse to fine with regard to texture. These units may be presented as follows **(Table A):**

Table A: The 11 soil units (on basis of depth and texture) of the Siwa Soils of the current study.

Units No.	Nomenclature of soil unit	Profile No.	Region
1	Deep, medium textured soils or medium over coarse-textured soils.	1, 4	El-Marqui, khamisa
2	Moderately deep to deep medium textured over fine-textured soils.	2,3	El-Marqui, khamisa
3	Deep, medium textured with surface fine-textured soils.	5	khamisa
4	Moderately deep or deep medium textured over fine-textured soils.	6,8	Siwa, Aghormi
5	Deep medium textured soils.	7	Siwa
6	Moderately deep, fine-textured soils.	9	Aghormi
7	Deep, coarse-textured soils.	10,11	Aghormi
8	Moderately deep, medium textured soils.	12,15	Qureishet, Abu-shrouf
9	Deep medium texture and/or medium textured over fine-textured soils.	13,17	Qureishet,El-Zeitun
10	Deep fine-textured soils.	14,16	Abu-shrouf, El-Zeitun
11	Shallow, medium textured soils.	18,19	Timeira

1- Deep medium- textured soils:

These are soils which are deep, and their texture is generally of medium nature (loamy in general). Soils of this unit are in El-Maraqui (profiles 1 and 2).

2-Moderately deep to deep medium-textured upper layers over fine- textured lower layers. The texture of these soils is mainly loamy. Soils of this unit are in El- Maraqui (profile 2) and Khamisa (profile 3).

3- Deep medium- textured soils having fine- textured surface. These soils are mainly loamy with clayey surface soils of this unit are in Khamisa (profile 5).

4- Moderately- deep to deep medium- textured upper over fine-textured lower layers. These soils are of loamy texture in the upper layer(s) and clayey texture in their lower layer (s). Soils of this unit are in Siwa (profile 6) and Aghormi (profile 8).

5-Deep medium- textured soils. These soils are deep with loamy texture in their profile. Soils of this unit are in Siwa (profile 7).

6- Moderately deep fine–textured soils. These soils have moderate depth and their texture is generally clayey. Soils of this unit are in Aghormi (profile 9).

7- Deep coarse- textured soils. These soils have a deep profile and their texture is mainly sandy all along the depth of the profile. Soils of this unit are in Aghormi (profiles 10 and 11).

8-Moderately deep medium- textured soils. These soils have deep profiles and are dominantly of loamy textures. Soils of this unit are in Qureishet (profiles 12 and 13).

9-Deep medium- textured to deep medium upper layer(s) over fine- texture lower layer (s). They are loamy or loamy over clayey soils. These soils are in Qureishet (profile 13 and El-Zeitun (profile 17).

10-Deep fine- textured soils. These soils are clayey all along their depth. Soils of this unit are in Abu-Shrouf (profile 14) and El-Zeitun (profile 16).

11-Shallow medium-textured soils. These soils are loamy shallow soils. Soils of this unit are in Timeira (profiles 18 and 19).

4.3. Contents of $CaCO_3$ and size distribution of its particles (Table 8):

4.3.1. Calcium carbonate:

Table 8 shows that total calcium carbonate content in the studied soils varied between 2.80 to 49.70 %. The highest content is found in the deepest layer (85–150 cm) of profile 8 of the Aghormi region, while the lowest is recorded in the deepest layer (70–150 cm) of profile 13 of the Qureishet region soils. Low contents of calcium carbonate in soils of Siwa was attributed to the parent material of Nubian sandstones **(DRC 2001)**.

4.3.2. Active calcium carbonate (Table 8):

Active carbonate content varied between 0.75 to 17.75 %. The highest content is found in the deepest layer (85–150 cm) of profile 8 of the Aghormi region soils while the lowest is recorded in the sub-surface layer (60–90 cm) of profile 1 of the El-Maraqui region soils.

Table 8: Contents and size distribution of $CaCO_3$ of soils of Siwa oasis.

Region	Profile No.	Depth, cm	%					
			Total $CaCO_3$	Active $CaCO_3$	2.0-0.2 mm Ø (coarse sand size)	0.2-0.02 mm Ø (fine sand size)	0.02-0.002 mm Ø (silt size)	< 0.002 mm Ø (clay size)
El-Maraqui	1	0-60	16.30	1.25	5.3	0.9	1.0	9.1
		60-90	15.10	0.75	2.4	7.8	4.0	0.9
		90-150	16.70	2.25	7.1	1.1	0.4	8.1
	2	0-30	19.80	5.25	11.0	1.0	3.6	4.2
		30-60	29.50	10.75	5.1	0.9	4.5	19.0
		60-90	32.30	7.25	3.8	1.9	9.6	17.0
		90-150	36.90	9.75	8.9	1.0	9.0	18.0
Khamisa	3	0-50	10.30	5.25	1.5	0.4	3.4	5.0
		50-90	16.50	6.25	1.5	0.8	10.2	4.0
	4	0-60	9.70	5.75	6.0	1.5	0.3	1.9
		60-90	11.50	2.25	2.3	1.0	3.4	4.8
		90-150	9.20	0.85	3.4	3.0	1.2	1.6
	5	0-40	14.90	10.25	4.0	2.1	6.8	2.0
		40-80	16.50	11.25	3.3	3.1	5.7	4.4
		80-150	21.19	9.25	5.6	4.7	4.5	7.1
Siwa	6	0-30	21.40	7.75	2.7	0.3	11.2	7.2
		30-60	27.60	14.25	5.3	1.0	13.3	8.0
		60-90	27.80	6.75	2.3	4.8	9.9	10.8
	7	0-55	14.80	9.25	3.5	0.5	7.9	2.9
		55-75	18.10	13.75	0.9	0.2	3.0	14.0
		75-150	19.50	14.25	0.7	1.8	12.0	5.0
Aghormi	8	0-45	19.00	16.00	3.8	1.0	7.1	7.1
		45-85	27.20	16.25	4.4	0.1	13.9	8.8
		85-150	49.70	17.75	1.6	6.9	10.2	31.0
	9	0-45	31.20	17.25	1.8	1.6	8.0	19.8
		45-90	29.80	15.75	7.2	1.4	8.2	13.0
	10	0-50	13.60	8.75	10.0	1.0	2.1	0.5
		50-90	16.70	7.75	7.1	5.9	2.1	1.6
		90-150	13.40	6.25	4.0	7.2	2.0	0.2

Table 8: Cont.

Region	Profile No.	Depth, (Cm.)	%					
			Total $CaCO_3$	Active $CaCO_3$	2.0-0.2 mm Ø (coarse sand size)	0.2-0.02 mm Ø (fine sand size)	0.02-0.002 mm Ø (silt size)	< 0.002 mm Ø (clay size)
Aghormi cont.	11	0-45	12.10	5.25	5.0	2.3	3.8	1.0
		45-95	11.90	4.75	1.7	8.6	1.0	0.6
		95-150	14.10	8.75	3.9	4.9	3.0	2.3
Qureishet	12	0-45	18.90	15.50	8.8	3.5	4.6	2.0
		45-60	20.60	16.75	6.9	2.1	10.6	1.0
		60-100	25.20	17.25	5.0	9.0	6.2	5.0
	13	0-45	4.20	2.25	1.0	0.7	1.3	1.2
		45-70	13.50	8.75	9.6	0.8	1.2	1.9
		70-150	2.80	1.75	0.5	0.6	0.8	0.9
Abu-shrouf	14	0-45	18.20	4.75	3.7	4.6	6.0	3.9
		45-95	26.90	7.75	7.6	0.2	8.1	10.0
		95-150	14.40	5.25	4.2	0.8	5.0	4.4
	15	0-45	14.70	11.75	1.3	4.9	4.4	4.1
		45-60	17.60	12.50	5.0	3.1	8.6	0.9
		60-100	20.50	10.00	2.6	4.9	10.0	3.0
EL-Zeitun	16	0-55	24.70	14.25	1.5	1.0	10.2	12.0
		55-90	17.60	12.75	1.3	0.9	6.4	9.0
		90-150	16.20	9.25	1.1	0.5	4.6	10.0
	17	0-55	10.10	8.25	2.1	0.8	3.0	4.2
		55-85	30.50	11.75	1.7	6.8	2.0	20.0
		85-150	34.60	14.25	0.6	3.0	14.0	17.0
Timeria	18	0-25	27.30	7.00	8.4	9.1	3.4	6.4
		25-50	14.10	10.25	3.1	2.3	4.8	3.9
	19	0-10	14.60	11.75	0.8	1.8	9.7	2.3
		10-40	15.20	12.75	3.4	4.4	2.3	5.1

Total $CaCO_3$ is determined by calcimeter; active $CaCO_3$ determined by the NH4-oxalate method; while size $CaCO_3$ distribution is the difference between particle size distribution of soil conducted by (a) pre-destruction of $CaCO_3$; and (b) no-destruction of $CaCO_3$.

4.3.3. Size distribution of $CaCO_3$ (contents of various sizes of $CaCO_3$ particles) (Table 8):

Calcium carbonate of the size range of 2.0 to 0.2 mm (i.e., the coarse sand size) varied between 0.5 to 11.0 %. The highest content is found in the surface layer (0–30 cm) of profile 2 of the El-Maraqui region soils while the lowest content is recorded in the deepest layer (70–150 cm) of profile 13 of the Qureishet region soils.

Contents of $CaCO_3$ of the 0.2 to 0.02 mm (i.e. the fine sand size) varied between 0.1 to 9.0 %. The highest content is found in the deepest layer (60–100 cm) of profile 12 of the Qureishet region soils while the lowest content is recorded in the sub-surface layer (45–85 cm) of profile 8 of the Aghormi region soils.

Contents of $CaCO_3$ of the 0.02 to 0.002 mm (i.e., the silt size) varied between 0.3 to 14.0 %. The highest content is found in the deepest layer (85–150 cm) of profile 17 of the El-Zeitun region soils while the lowest content is recorded in the surface layer (0–60 cm) of profile 4 of the Khamisa region soils.

Contents of $CaCO_3$ of the < 0.002 mm (i.e., the clay size) varied between 0.2 to 31.0 %. The highest content is found in the deepest layer (85–150 cm) of profile 8 of the Aghormi region soils while the lowest content is recorded in the deepest layer (90–150 cm) of profile 10 of the Aghormi region.

4.4. Other analyses:

4.4.1. Gypsum (Table 9):

Gypsum ranged from 0.05 to 2.94 % with an average of 0.88 %. The lowest was in the deep layer (90–150 cm) of profile 10 of the Aghormi region soils, while highest were in the sub-surface layer (10–40 cm) of profile 19 of the Timeira El-Masser region soils.

4.4.2. Saturation percentage (Table 9):

The saturation percentage (S.P) ranged from 20.00 to 65.00 %with an average of 38.39 % .The highest was in the deep layer (60-100 cm) of profile 12 in soils of the Qureishet region soils, while the lowest was in the surface layer (0-50 cm) of profile 10 of the Aghormi region soils.

4.4.3. Organic matter (Table 9):

Organic matter content in the studied soils is low, not exceeding 2.63 %. It varies from 0.06 to 2.63 %. About 55 % of the samples contained from 1.00 to 2.63 % organic matter. The lowest content is found in the deep layer (90–150 cm) of profile 10 of the Aghormi region soils while the highest content is recorded in the surface (0–45 cm) layer of profile 8 in same region soils.

4.4.4. Soil salinity (Table 9):

The studied soils vary widely from non-saline to extremely saline. Values of electric conductivity (EC) of the saturation extract of soil range from 1.52 to 160.80 dS/m. The lowest is recorded in the sub-surface layer (60–90 cm) of profile 4 of the Khamisa region soils while the highest is recorded in the sub-surface layer (10–40 cm) of profile 19 of the Timeira El-Masser region soils.

Table 9: Soil pH, organic matter, gypsum, saturation percent(SP), salinity(expressed as electric conductivity (EC), soluble ions, sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) of soil paste extract of soils of Siwa oasis.

Region	Profile No.	Depth (cm)	Gypsum (%)	SP	Organic matter (%)	EC (dS/m)	pH (soil paste)	Soluble ions mmolc/L								SAR	PAR
								Na^+	K^+	Ca^{+2}	Mg^{+2}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$		
El-Maraqui	1	0 - 60	1.41	25.00	0.87	6.52	7.94	29.70	2.60	25.00	20.00	0.00	7.00	30.00	40.30	6.27	0.55
		60 -90	1.31	25.00	0.58	4.28	7.95	10.00	1.80	25.00	16.00	0.00	4.00	18.00	30.80	2.21	0.40
		90 - 150	1.15	25.00	1.16	10.65	7.94	65.95	3.80	40.00	26.00	0.00	10.00	60.75	65.00	11.49	0.66
	2	0 - 30	0.31	33.00	2.31	5.96	7.65	36.39	4.50	18.00	10.00	0.00	6.00	25.00	37.89	9.73	1.20
		30 - 60	0.27	40.00	2.60	6.85	7.75	30.00	4.40	25.00	21.40	0.00	9.00	25.50	46.30	6.22	0.91
		60 -90	1.17	48.50	2.02	8.85	7.59	48.25	3.10	36.00	24.00	0.00	5.00	44.50	61.85	8.80	0.57
		90 - 150	0.82	50.00	1.44	5.81	7.02	33.20	2.10	20.00	15.00	0.00	5.00	26.06	37.14	7.94	0.50
Khamisa	3	0 -50	1.36	25.00	0.29	13.84	7.48	94.50	12.90	40.00	25.00	0.00	8.00	94.00	70.40	16.58	2.26
		50 -90	1.16	47.00	1.70	29.40	7.42	267.00	11.40	60.00	51.00	0.00	10.00	268.50	110.90	35.84	1.53
	4	0 - 60	0.29	36.00	0.81	2.73	7.49	15.00	1.50	4.80	6.00	0.00	1.20	9.00	17.10	6.47	0.65
		60 -90	0.15	30.00	0.52	1.52	7.53	4.50	1.10	3.60	6.00	0.00	1.50	6.90	6.80	2.05	0.50
		90 - 150	0.22	27.50	0.84	2.85	7.50	10.70	1.20	10.00	6.00	0.00	3.00	15.60	9.30	3.78	0.42
	5	0-40	0.18	50.00	1.16	3.20	7.51	11.80	1.20	14.00	5.00	0.00	4.00	16.60	11.40	3.83	0.39
		40-80	0.29	50.00	1.42	2.85	7.65	10.50	1.20	1.00	5.80	0.00	3.60	16.00	8.90	5.71	0.65
		80-150	1.43	45.00	1.96	19.90	7.56	119.71	7.20	80.00	50.80	0.00	25.00	120.00	112.71	14.80	0.89
Siwa	6	0 - 30	0.35	43.00	2.60	4.24	7.17	24.00	2.10	14.00	8.00	0.00	3.50	24.50	20.10	7.23	0.63
		30 - 60	0.22	48.00	0.84	4.62	7.27	26.00	1.70	16.00	9.00	0.00	9.00	31.50	12.20	7.34	0.48
		60 -90	0.24	45.00	0.58	4.75	7.47	27.40	1.70	18.00	8.00	0.00	17.00	28.20	9.90	7.59	0.47
	7	0 -55	0.34	33.00	1.16	14.31	7.86	100.70	8.30	46.00	25.00	0.00	5.00	63.75	111.25	17.89	1.47
		55 -75	0.13	36.00	1.73	11.75	7.88	79.00	3.50	35.50	28.00	0.00	5.00	105.00	36.00	14.03	0.62
		75 -150	0.12	35.00	2.31	13.72	7.65	100.00	3.80	35.00	34.00	0.00	6.00	111.00	55.80	17.04	0.65
Aghormi	8	0 45	0.43	36.00	2.63	4.90	7.20	20.40	1.80	21.00	12.80	0.00	7.00	23.75	25.25	4.96	0.44
		45 -85	1.10	45.00	2.54	11.69	7.32	64.50	2.80	46.00	32.00	0.00	8.00	76.50	60.80	10.34	0.45
		85 -150	1.10	48.00	2.49	12.04	7.37	71.50	2.60	48.00	27.00	0.00	7.00	89.00	53.10	11.68	0.42
	9	0 -45	0.41	45.00	2.43	13.65	7.13	80.50	5.80	51.00	38.00	0.00	9.00	96.25	70.05	12.07	0.87
		45 -90	0.34	49.00	1.16	6.95	7.08	30.40	2.30	29.30	18.00	0.00	6.00	46.00	28.00	6.26	0.47

Table 9: cont.

Region	Profile No.	Depth, (cm)	Gypsum (%)	SP	Organic matter (%)	EC (ds/m)	pH (paste)	Soluble ions mmolc/L								SAR	PAR
								Na^+	K^+	Ca^{+2}	Mg^{+2}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$		
Aghormi cont.	10	0 -50	0.70	20.00	0.29	19.87	8.04	166.2	11.80	44.00	35.00	0.00	3.00	90.00	164.00	26.46	1.88
		50 -90	0.17	24.00	0.14	3.37	8.17	8.0	2.60	13.00	10.00	0.00	5.00	12.00	16.60	2.36	0.77
		90 -150	0.05	24.00	0.06	4.04	7.98	9.0	2.30	14.70	14.00	0.00	5.00	15.00	20.00	2.37	0.61
	11	0 -45	0.20	28.00	0.58	1.56	7.59	7.8	1.20	3.00	3.00	0.00	6.00	8.00	1.00	4.51	0.69
		45-95	0.17	25.00	0.26	3.01	7.78	6.0	1.70	11.00	11.30	0.00	6.00	10.00	14.00	1.80	0.51
		95 -150	0.10	25.00	0.17	3.60	7.54	9.0	1.30	15.00	9.70	0.00	7.00	13.00	15.00	2.56	0.37
Qureishet	12	0 -45	1.49	50.00	1.73	3.75	7.51	6.3	1.10	20.00	9.60	0.00	7.00	6.00	24.00	1.64	0.29
		45 -60	1.38	51.00	2.02	3.78	7.49	6.7	0.90	21.00	8.40	0.00	7.00	6.25	23.75	1.75	0.23
		60 -100	1.40	65.00	2.31	3.33	7.54	5.2	0.60	19.00	8.20	0.00	5.00	6.00	22.00	1.41	0.16
	13	0 45	1.48	37.50	2.57	4.49	7.51	9.1	1.10	24.00	15.80	0.00	8.00	7.00	35.00	2.04	0.25
		45 -70	1.39	35.50	2.10	4.37	7.62	10.0	0.85	22.00	17.15	0.00	7.00	11.00	32.00	2.26	0.19
		70 -150	1.41	38.00	1.16	3.28	7.69	3.9	0.60	15.50	12.00	0.00	6.00	5.00	21.00	1.05	0.16
Abu-shrouf	14	0 -40	0.37	46.50	2.02	2.55	7.53	9.5	1.30	8.80	6.00	0.00	2.50	12.25	10.85	3.49	0.48
		45 -95	1.44	39.00	0.81	8.85	7.81	50.7	4.90	34.35	18.00	0.00	8.80	55.00	44.20	9.91	0.96
		95 -150	1.37	40.00	0.84	10.58	7.73	63.0	3.30	37.00	28.00	0.00	4.00	67.50	59.80	11.05	0.58
	15	0 35	1.38	37.00	1.10	8.49	7.54	35.5	1.30	30.00	36.00	0.00	8.00	30.00	64.80	6.18	0.23
		35 -85	1.44	43.00	0.52	10.43	7.54	51.5	2.70	40.00	36.00	0.00	10.00	60.00	60.20	8.36	0.44
		85 -130	1.24	46.00	0.49	8.82	7.54	37.0	2.20	41.80	25.00	0.00	6.00	39.00	61.00	6.40	0.38
El- zeitun	16	0 55	1.41	45.50	0.75	12.76	7.69	77.0	2.70	49.00	29.00	0.00	10.00	89.75	57.95	12.34	0.43
		55 -90	1.42	42.00	0.52	9.50	7.67	51.2	2.80	39.00	20.00	0.00	6.00	50.00	57.00	9.43	0.52
		90- 150	1.53	40.00	1.04	10.41	7.75	72.0	3.20	37.00	18.00	0.00	10.00	75.00	45.20	13.74	0.61
	17	0 -55	2.70	47.50	2.20	88.5	7.16	1060.0	41.0	100.0	109.0	0.00	12.0	1200.0	98.0	103.7	4.01
		55 -85	0.23	51.00	1.68	14.70	7.72	85.0	4.60	47.40	47.00	0.00	6.00	82.40	95.60	12.37	0.67
		85 -150	0.34	52.00	1.62	16.65	7.67	108.5	3.20	52.00	46.00	0.00	7.00	133.75	68.95	15.50	0.46
Timeira	18	0 -25	0.13	23.50	0.58	5.00	7.51	12.8	2.20	26.00	16.00	0.00	5.00	25.00	27.00	2.79	0.48
		25 -50	1.35	32.50	0.29	7.63	7.24	34.1	2.30	35.60	20.00	0.00	3.00	43.75	45.25	6.47	0.44
	19	0 -10	2.21	21.50	0.72	77.30	7.23	575.0	51.2	284.0	266.0	0.00	4.0	1093.5	78.7	34.7	3.05
		10-40	2.94	23.00	1.01	160.80	7.07	1767.0	128.0	366.0	199.0	0.00	5.0	2404.2	63.8	105.1	7.61

4.4.5. Soil pH (Table 9):

Table 9 shows that the studied soils have pH values which vary between (7.07 to 8.17). The lowest pH value is found in the (10–40 cm) sub-surface layer of profile 19 of the Timeira El-Masser region soils while the highest value is recorded in the (50–90 cm) subsurface layer of profile 10 of the Aghormi region soils.

4.4.6. Soluble ions (Table 9):

Soluble cations in the saturation extract are dominated by Na^{+} followed by Ca^{++} and Mg^{++} while K^{+} is the least soluble cation. Soluble anions are dominated by Cl^{-} followed by $SO_4^{=}$ while HCO_3^{-} is the least soluble component. No $CO_3^{=}$ were found in all the studied soils.

4.4.7. Sodium adsorption ratio (SAR), (Table 9):

SAR of the saturation extract of soils ranged from 1.05 to 105.1 with an average of 12.41. The lowest was in the deepest layer (70–150 cm) of profile 13 of Qureishet region soils while the highest was in the sub-surface layer (10–40 cm) of profile 19 of the Timeira El-Masser region soils.

4.4.8. Potassium adsorption ratio (PAR), (Table 9):

PAR of the saturation extract of soils ranged from 0.16 to 7.61 with an average of 0.86. The lowest was in the deepest layers (60–100 cm), (70–150 cm) of profiles 12 and 13 of Qureishet region soils while the highest was in the deepest layer (10–40 cm) of profile 19 of Timeira El-Masser region soils.

4.5. Cation exchange characteristics and surface area of soil particles (Table 10):

4.5.1. Cation exchange capacity (CEC):

Data in **Table 10** show that the cation exchange capacity values vary widely between the studied soils and range from 17.50 to 40.25 $cmol_c/kg$ soil. The lowest value is found in the (50–90 cm) sub-surface layer of profile 10 of the Aghormi region soils. The highest value is in the (90–150 cm) deep layer of profile 2 in the El-Maraqui region soils.

4.5.2. Exchangeable cations:

Table 10 reveals that exchangeable cations vary widely between the studied soils and followed the pattern: $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$.

4.5.3. Total exchangeable cations:

Data tabulated in **Table 10** show that total exchangeable cations of Ca, Mg, Na and K vary widely between the studied soils and range from 17.01 to 39.15 $cmol_c/kg$ soil with an average of 27.26 $cmol_c/kg$ soil. The lowest and highest were the same soils mentioned regarding CEC.

4.5.4. Exchangeable sodium percentage (ESP actual):

ESP (actual) ranged from 0.14 to 21.99 with an average of 5.90. The lowest was in the (0–50 cm) surface layer of profile 10 in the Aghormi region soils. The highest was in the (50–90 cm) deep layer of profile 3 in the Khamisa region soils,

Table 10: Cation Exchange Capacity (CEC), exchangeable, Cations ,exchangeable sodium percent (ESP), Exchangeable, potassium percent (EPP) and surface area of Soils of Siwa Oasis.

Region	Profile No.	Depth, (cm.)	CEC $cmol_c$/ kg soil	Exchangeable Cations ($cmol_c$ / kg soil)				Total Exch. Cati.	ESP (act.)	ESP (calc.)	EPP	Surface area M^2/g soil
				Na^+	K^+	Ca^{+2}	Mg^{+2}					
El-Maraqui	1	0 - 60	24.00	0.52	0.23	13.37	5.50	19.62	2.17	7.38	0.96	34.08
		60 -90	25.00	0.45	0.21	20.00	6.60	27.26	1.80	1.96	0.84	34.71
		90 - 150	21.75	0.65	0.32	16.00	3.35	20.52	2.99	13.33	1.47	34.91
	2	0 - 30	28.75	0.88	0.97	15.00	11.67	28.52	3.06	11.58	3.37	40.29
		30 - 60	33.75	1.40	1.36	18.00	9.14	29.90	4.15	7.32	4.03	41.25
		60 -90	39.25	1.52	1.23	25.00	4.83	32.58	3.87	10.46	3.13	41.22
		90 - 150	40.25	2.40	1.90	19.60	15.25	39.15	5.96	9.41	3.33	41.16
Khamisa	3	0 -50	28.75	2.42	0.76	17.00	5.37	25.55	8.42	18.86	2.64	33.82
		50 -90	33.75	7.42	2.12	18.00	7.60	35.17	22.07	33.95	6.28	41.35
	4	0 - 60	27.25	1.38	0.40	19.00	5.78	26.56	5.06	7.60	1.47	38.71
		60 -90	25.50	1.34	0.41	17.89	3.82	23.46	5.25	1.73	1.61	38.75
		90 - 150	26.00	1.63	0.39	11.72	5.83	19.57	6.27	4.11	1.50	35.61
	5	0-40	38.75	2.26	0.66	19.59	3.72	26.23	5.83	4.18	1.70	39.32
		40 -80	34.75	2.71	0.76	27.30	3.75	34.52	7.80	6.69	2.19	40.10
		80- 150	32.50	2.17	0.66	21.00	3.71	27.54	6.68	17.00	2.03	40.01
Siwa	6	0-30	34.75	2.27	0.62	19.40	3.66	25.95	6.53	8.55	1.78	39.81
		30-60	27.75	2.31	0.70	19.23	1.57	23.81	8.32	8.70	2.52	40.96
		60-90	37.00	1.85	0.60	21.19	5.64	29.28	5.00	9.04	1.62	41.39
	7	0 -55	25.50	2.40	0.65	17.00	5.17	25.22	9.41	20.10	2.55	39.03
		55 -75	28.75	0.72	0.93	20.00	4.99	26.64	2.50	16.20	3.23	39.01
		75 -150	27.25	0.28	0.95	21.20	2.81	25.24	1.03	19.25	3.49	39.30
Aghormi	8	0- 45	29.25	1.35	0.76	18.60	7.54	28.25	4.62	5.72	2.60	40.64
		45 -85	34.75	1.18	0.75	20.20	10.56	32.69	3.40	12.28	2.16	41.18
		85 -150	37.00	1.35	0.70	22.30	8.70	33.25	3.65	13.77	1.89	41.35
	9	0 -45	37.50	0.98	2.16	24.07	6.29	33.50	2.61	14.14	5.76	41.25
		45 -90	33.75	1.51	0.31	25.80	4.12	31.74	4.47	7.38	0.92	41.05

Table 10: Cont.

Region	Profile NO.	Depth, (cm.)	CEC cmol$_c$/ kg soil	Exchangeable cations (cmol$_c$ / kg soil)				Total Exch. Cati.	ESP (Act.)	ESP (calc.)	EPP	Surface area m^2 /g soil
				Na^+	K^+	Ca^{+2}	Mg^{+2}					
Aghormi cont.	10	0 -50	28.75	0.04	0.40	22.10	5.30	27.84	0.14	27.37	1.39	34.88
		50 -90	17.50	0.77	0.48	14.00	1.76	17.01	4.40	2.18	2.74	34.84
		90 -150	21.75	0.74	0.56	12.20	5.66	19.16	3.40	2.20	2.57	32.79
	11	0 -45	20.75	0.38	0.62	11.80	5.91	18.71	1.83	5.08	2.99	33.82
		45-95	20.75	0.81	0.58	10.60	7.72	19.71	3.90	1.37	2.80	32.19
		95 -150	20.75	0.85	0.61	10.50	7.76	19.72	4.10	2.45	2.94	32.17
Qureishet	12	0 45	31.50	0.55	0.28	16.40	7.52	24.75	1.75	1.15	0.89	40.97
		45 60	32.50	0.44	0.29	21.10	9.57	31.40	1.35	1.29	0.89	41.18
		60 100	35.75	0.58	0.30	22.00	11.47	34.35	1.62	0.91	0.83	41.19
	13	0 45	26.00	0.52	0.22	12.80	9.40	22.94	2.00	1.72	0.85	39.00
		45 -70	25.50	0.90	0.21	17.60	5.39	24.10	3.53	2.03	0.82	38.19
		70 -150	25.50	0.51	0.16	11.30	11.54	23.51	2.00	0.29	0.63	38.01
Abu-shrouf	14	0 45	37.50	1.51	0.55	17.40	1.71	21.17	4.03	3.74	1.47	41.06
		45 95	39.25	3.16	0.89	25.90	7.30	37.25	8.03	11.72	2.27	40.83
		95 150	40.00	3.08	0.79	16.20	18.18	38.25	7.70	13.08	1.96	40.73
	15	0- 35	26.00	1.13	0.37	15.00	6.67	23.17	4.35	7.28	1.42	39.65
		35 -85	20.00	2.79	0.68	6.00	10.45	19.92	13.95	9.97	3.40	40.99
		85 -130	31.50	2.30	0.62	17.04	6.85	26.81	7.30	7.57	1.97	41.00
El-Zeitun	16	0 -55	39.25	4.06	0.52	22.10	2.68	29.36	10.34	14.48	1.32	41.27
		55 -90	39.90	5.77	0.86	25.20	4.16	35.99	14.46	11.20	2.16	41.25
		90 150	39.77	3.94	0.99	21.50	9.28	35.71	9.91	15.84	2.49	40.97
	17	0 -55	19.50	2.55	1.99	9.68	5.00	19.22	13.10	60.21	10.21	41.05
		55 -85	37.00	3.58	1.05	17.58	7.60	29.81	9.68	14.52	2.84	41.31
		85 -150	35.75	3.46	1.01	21.29	9.61	35.37	9.68	17.70	2.83	41.27
Timeira	18	0 -25	32.50	0.52	0.41	23.90	3.62	28.45	1.60	2.78	1.26	37.06
		25 -50	24.00	0.45	0.49	12.70	10.30	23.94	1.88	7.60	2.04	38.81
	19	0 -10	28.25	3.64	2.14	20.00	2.28	28.06	12.88	33.26	7.58	37.51
		10 40	25.00	4.16	2.18	13.00	5.42	24.76	16.64	60.55	8.72	38.63

ESP (act.) i.e. determined using actual values of exchangeable Na, K, Ca, Mg; ESP (calc.)i.e. determined by computation using the SAR value of the saturation extract, according to equation of USDA(1954)

4.5.5. ESP (calculated):

ESP, calculated by means of the USDA equation **(USDA, 1954)**, range from 0.29 to 60.55 with an average of 11.67. The lowest was in the (70–150 cm) deep layer of profile 13 in the Qureishet region soils. The highest was in the (10–40 cm) deep layer of profile 19 in the Timeira El-Masser region soils,

4.5.6. Exchangeable potassium percentage (EPP):

EPP ranged from 0.63 to 10.21 with an average of 2.58. The lowest was in the (70–150 cm) deep layer of profile 13 in the Qureishet region soils, while highest was in the (0–55 cm) surface layer of profile 17 in the El-Zeitun region soils,

4.5.7. Total surface area of soil particles:

Data listed in **Table 10** show that the total surface area of soil particles ranges between 32.17 and 41.39 m^2/g soil with an average of 38.94 m^2/g soil. The lowest was in the (95–150 cm) deep layer of profile 11 in the Aghormi region soils. The highest was in the (60–90 cm) deep layer of profile 6 in the Siwa region soils,

4.6. Total and available of contents nutrients (Table 11):

4.6.1. Macronutrients:

4.6.1.1. Nitrogen (N):

Total N varied between 140 to 3360 mg kg^{-1} with an average of 1234 mg kg^{-1}. The lowest was in the deepest layer (85–130 cm) of profile 15 of the Abu-Shrouf region soils, while the highest is in the deepest (95–150 cm) layer of profile 14 of the Abu-Shrouf region soils.

Table 11: Total (Tot.) and available (Av.)* nutrients in soils of Siwa oasis.

Region	Profile No.	Depth, (cm.)	N ($mgkg^{-1}$)		P ($mgkg^{-1}$)		K ($mgkg^{-1}$)		Fe ($mgkg^{-1}$)		Mn ($mgkg^{-1}$)		Zn ($mgkg^{-1}$)		Cu ($mgkg^{-1}$)	
			Tot.	AV.*	Tot.	AV.*	Tot.	AV.*	Tot.	AV.*	Tot.	AV.*	Tot.	AV.*	Tot.	AV.*
El-Maraqui	1	0 - 60	420	49	88.3	10.8	550	86	2060	28.7	92.7	9.3	50.00	0.46	3.41	0.25
		60 -90	840	56	56.0	4.3	99	84	1890	2.0	61.9	9.8	8.51	0.67	2.31	0.31
		90 - 150	1260	42	63.2	6.9	650	139	2294	8.4	78.3	11.2	8.43	0.59	1.86	0.35
	2	0 - 30	560	83	249.2	6.6	1400	600	6110	143.9	235.8	112.5	45.62	4.04	3.94	0.96
		30 - 60	840	70	71.8	12.5	450	580	1762	30.8	65.9	54.8	10.71	4.06	0.98	3.26
		60 -90	700	82	413.6	8.9	1900	450	10020	64.8	450.7	147.0	43.08	2.62	6.65	4.39
		90 - 150	420	63	84.0	11.8	4325	520	19840	44.4	414.4	51.7	72.65	1.30	2.98	4.06
Khamisa	3	0 -50	700	59	146.5	9.1	800	340	2232	2.4	58.0	9.5	10.21	1.02	4.84	0.35
		50 -90	840	49	298.7	3.2	2725	720	1024	1.3	242.3	85.3	28.30	0.96	5.38	1.70
	4	0 - 60	1960	47	171.6	8.1	800	220	3971	8.8	100.5	43.4	14.47	2.41	4.96	1.04
		60 -90	2660	70	94.8	13.0	650	176	2067	17.7	50.3	16.2	9.12	1.66	2.76	0.63
		90 - 150	2800	77	43.8	13.7	625	185	2000	38.0	47.1	14.6	8.37	2.29	2.05	0.87
	5	0-40	1120	49	138.6	12.0	1025	280	4537	260.0	147.0	97.2	39.92	3.71	5.27	1.05
		40 -80	1680	49	158.0	14.6	1600	300	7000	41.0	240.6	94.5	41.61	6.22	4.66	0.91
		80- 150	1680	70	38.8	9.0	1225	280	6730	117.3	380.2	305.5	44.81	1.31	9.53	3.86
Siwa	6	0 - 30	700	84	292.9	10.4	1100	270	5445	194.8	156.5	73.9	21.59	4.52	16.40	1.41
		30 - 60	1260	56	328.1	12.1	2525	310	10565	10.3	287.3	128.5	33.22	1.67	5.41	0.70
		60 -90	840	49	112.0	10.3	2350	380	20945	7.3	288.5	130.8	31.53	1.15	4.70	1.73
	7	0 -55	2800	49	155.1	11.0	1000	270	5395	8.5	176.9	42.0	178.80	5.21	6.11	3.43
		55 -75	1260	21	77.5	6.1	1050	280	4837	2.6	178.0	56.0	68.25	2.84	4.22	1.70
		75 -150	1960	35	26.6	2.8	1100	280	5625	23.4	196.3	46.6	24.47	2.60	6.59	1.30
Aghormi	8	0-45	2660	56	361.9	12.5	1500	350	7365	277.7	178.6	23.1	29.39	4.53	8.62	0.19
		45 -85	2419	56	58.9	14.2	1950	300	21075	7.1	253.3	63.0	35.45	1.58	8.91	0.70
		85 -150	840	42	242.7	11.2	2050	300	8580	28.1	215.5	163.1	36.21	0.87	7.60	0.66
	9	0 -45	1400	56	649.8	16.2	3550	800	16810	5.6	341.3	79.5	50.35	5.44	13.59	4.49
		45- 90	2800	70	340.3	18.6	1550	520	6400	34.7	166.1	90.2	41.27	3.22	6.13	4.55
	10	0 -50	840	28	17.2	4.3	775	230	2234	29.5	75.1	7.7	58.50	3.02	2.84	0.18
		50-90	1260	35	27.3	2.2	500	106	1859	16.5	66.4	8.8	59.70	0.68	3.07	0.20
		90 -150	1120	42	5.0	0.5	525	120	1746	44.2	61.0	8.0	59.35	0.61	2.40	0.20

Table 11:Cont.

Region	Profile No.	Depth, (cm.)	N ($mgkg^{-1}$)		P ($mgkg^{-1}$)		K ($mgkg^{-1}$)		Fe ($mgkg^{-1}$)		Mn ($mgkg^{-1}$)		Zn ($mgkg^{-1}$)		Cu ($mgkg^{-1}$)	
			Total	AV.**	Total	AV.*	Total	AV.*	Total	AV.*	Total	AV.*	Total	AV.*	Total	AV.*
Aghormi Cont.	11	0 -45	980	28	137.9	3.4	550	82	1978	19.5	85.5	9.5	11.94	0.64	2.93	0.21
		45 -95	980	42	7.9	0.6	575	74	2536	33.9	84.2	6.0	80.70	0.66	3.91	0.98
		95 -150	1008	63	9.3	1.8	550	82	2179	83.0	81.1	6.7	12.54	0.48	2.85	0.20
Qureishet	12	0 -45	966	70	363.3	9.8	1175	148	5185	5.3	366.1	171.2	21.43	2.24	3.86	0.51
		45 -60	1120	56	228.3	6.9	1350	132	5050	17.3	303.4	157.7	21.40	1.76	6.58	0.60
		60 -100	1820	49	203.9	12.8	1300	152	5595	9.4	268.2	109.9	19.46	1.36	3.13	0.43
	13	0 -45	1400	42	75.4	17.2	1150	52	5945	27.1	139.4	12.0	47.85	0.37	11.79	1.90
		45 -70	1666	63	74.7	16.5	1400	65	6100	1.4	134.9	10.8	16.57	0.72	3.55	0.40
		70 -150	1386	49	12.9	11.7	575	36	5756	1.3	57.5	9.7	11.28	0.35	3.89	0.17
Abu-Shrouf	14	0 -45	700	35	517.7	3.7	2450	620	9475	7.5	414.8	99.8	33.44	2.35	6.99	0.66
		45 -95	840	42	71.8	12.9	1800	380	8985	1.9	366.0	84.7	121.10	2.01	3.12	0.85
		95 -150	3360	28	440.1	4.3	2800	340	17580	9.3	473.3	74.7	30.50	1.18	3.55	0.87
	15	0 -35	560	49	179.5	9.8	1150	173	6090	36.5	274.8	46.1	18.40	3.36	3.36	0.72
		35 -85	280	56	18.7	0.9	425	320	1325	13.4	58.1	68.7	7.45	3.24	1.27	0.79
		85 -130	140	70	221.1	4.6	1700	260	6540	14.8	281.4	49.2	18.57	1.35	3.05	0.66
El-Zeitun	16	0 -55	560	28	616.0	11.4	2800	270	11250	1.4	553.1	133.9	34.35	1.29	6.08	1.20
		55 -90	980	28	127.1	3.7	2000	410	8130	3.2	348.3	90.5	96.75	1.18	6.04	0.97
		90 -150	980	28	402.8	16.7	2350	420	20925	3.5	523.5	100.3	36.72	1.23	4.86	0.91
	17	0 -55	420	49	194.6	6.6	2725	1450	8010	1.6	382.8	101.7	45.33	2.01	6.96	1.12
		55 -85	420	42	481.8	17.7	3050	460	10705	1.2	532.5	150.1	30.43	1.02	6.06	1.99
		85-150	560	28	186.0	8.6	2400	410	8835	1.3	429.3	168.9	47.04	1.22	3.92	1.67
Timera	18	0- 25	1540	42	10.1	8.9	1000	160	20570	39.8	576.0	31.9	25.77	0.84	4.08	0.40
		25 -50	1260	49	463.1	10.7	1300	145	23550	5.4	836.0	9.8	47.82	0.88	2.11	0.21
	19	0 -10	700	42	283.6	6.1	2050	1060	22415	53.9	603.5	32.7	80.20	0.72	3.56	0.60
		10-40	1400	28	109.9	11.1	2650	1880	22840	21.0	621.0	13.9	89.45	0.51	2.95	0.35

* Available nutrients extracted as follows: N (NO_3+NH_4.N, Kcl extract), others (NH_4HCO_3-DTPA extract).

Available N varied between 21 to 84 mg kg^{-1} with an average of 50 mg kg^{-1}. The lowest was in the sub-surface (55–75 cm) layer of profile 7 of the Siwa region soils, while the highest is in the surface (0–30 cm) layer of profile 6 of the Siwa region soils.

4.6.1.2. Phosphorus (P):

Total phosphorus varied between 5.0 to 649.8 mg kg^{-1} with an average of 189.8 mg kg^{-1}. The lowest is in the deepest (90–150 cm) layer of profile 10 of the Aghormi region soils, while the highest was in the surface (0–45 cm) layer of profile 9 of the Aghormi region soils.

Available phosphorus (NH_4-bicarbonate-DTPA extract) varied between 0.5 to 18.6 mg kg^{-1} with an average of 9.17 mg kg^{-1}. The lowest was in the deepest (90–150 cm) layer of profile 10 of the Aghormi region soils, while the highest is in the deepest (45–95 cm) layer of profile 9 of the Aghormi region soils.

4.6.1.3. Potassium:

Total potassium varied between 99 to 4325 mg kg^{-1} with an average of 1512 mg kg^{-1}. The lowest is in the sub-surface layer (60–90 cm) of profile 1 of the El-Maraqui region soils, while the highest was in the deepest layer (90–150 cm) layer of profile 2 of the El-Maraqui region soils.

Available potassium varied between 36 to 1880 mg kg^{-1} with an average of 353 mg kg^{-1}. The lowest was in the deepest layer (70–150 cm) layer of profile 13 of Qureishet, while the highest is in the deepest layer (10–40 cm) of profile 19 of the Timeira El-Masser region soils.

4.6.2. Micronutrients:

4.6.2.1. Iron:

Total iron varied between 1024 to 23550 mg kg^{-1} with an average of 8147 mg kg^{-1}. The lowest is in the deepest layer (50–90 cm) of profile 3 of the Khamisa region soils, while the highest is in the deepest layer (25–50 cm) of profile 18 of the Timeira El-Masser region soils.

Available iron varied between 1.2 to 277.7 mg kg^{-1} with an average of 35.44 mg kg^{-1}. The lowest is in the sub-surface layer (55–85 cm) of profile 17 of the El-Zeitun region soils, while the highest is in the surface layer (0–45 cm) of profile 8 of the Aghormi region soils.

4.6.2.2. Manganese:

Total manganese varied between 47.1 to 836.0 mg kg^{-1} with an average of 261 mg kg^{-1}. The lowest is in the deepest layer (90–150 cm) of profile 4 of the Khamisa region soils, while the highest is in the deepest layer (25-50 cm) of profile 18 of Timera El-Masser region soils.

Available manganese varied between 6.0 to 305.5 mg kg^{-1} with an average of 69.0 mg kg^{-1}. The lowest is in the sub-surface layer (45–95 cm) of profile 11 of the Aghormi region soils, while the highest is in the deepest layer (85–150 cm) of profile 5 of the Khamisa region soils.

4.6.2.3. Zinc:

Total zinc varied between 7.45 to 178.80 mg kg^{-1} with an average of 40.0 mg kg^{-1}. The lowest is in the sub-surface layer (35–85 cm) of profile 15 of the Abu-Shrouf region soils, while the highest is in the surface layer (0–55 cm) of profile 7 of the Siwa region soils.

Available zinc varied between 0.35 to 5.44 mg kg^{-1} with an average of 1.93 mg kg^{-1}. The lowest is in the deepest layer (70–150 cm) of profile 13 of the Qureishet region soils, while the highest is in the surface layer (0–45 cm) layer of profile 9 of the Aghormi region soils.

4.6.2.4. Copper:

Total copper varied between 0.98 to 13.59 mg kg^{-1} with an average of 4.97 mg kg^{-1}. The lowest is in the sub-surface layer (30–60 cm) of profile 2 of the El-Maraqui region soils, while the highest is in the surface layer (0–45 cm) layer of profile 9 of the Aghormi region soils.

Available copper varied between 0.17 to 4.55 mg kg^{-1} with an average of 1.20 mg kg^{-1}. The lowest is in the deepest layer (70–150 cm) layer of profile 13 of the Qureishet region soils, while the highest is in the deepest layer (45–90 cm) of profile 9 of the Aghormi region soils.

4.7. Depthwise distribution of total contents of each micronutrient:

The weighted mean (W) of the concentration of an element in a soil profile (or solum) and the concentration (S) of that element in the surface horizon (or layer) are used to obtain a measure called the trend (T) which assesses status of elements in the soil. The equation for this is as follows **(Oertel and Giles, 1963)**:

$T = (W - S)/W$; when W is greater than S

Or $T = (W - S)/S$; when S is greater than W

To work out a relationship between the distributions of trace elements and studied soils, the statistical measures; weighted mean, trend and specific range are calculated according to **Oertel and Giles, (1963)**. One way of assessing content distribution of elements is by using some specific equations of statistical nature. The weighted mean concentration of an element for the profile is obtained by multiplying the concentration of the element in each horizon (or layer) of the profile (or solum) by the thickness of the horizon (or layer) and dividing the sum of these products by the total thickness of the profile (or solum). The weighted mean gives an overall mean of the concentration for the entire profile depth (or solum depth). In this respect. **Ortel and Giles (1963)** concluded that the weighted mean appears to be most satisfactory measure of trace element status in the soil profile.

All values for (T) lie in the range of –1 to +1 and are in a sense, symmetrical when (T) is small. But distorted when (T) is large because a value of +1 is possible whereas a values of –1 is impossible.

A small value for T does not necessarily imply a small range in concentration throughout the profile. Definite information on this feature is therefore provided by the specific range defined by:

$$R = (H - L) / W$$

Where, R is the specific range, H is the highest and L is the lowest observed concentration in the solum and W is the weighted mean.

In this connection, a small value for (T) may be associated with any value for (R). But a large value for (T) is necessarily associated with at least a moderately large value for (R). Values for

(R) can not be negative but where there is no definite upper limit; values greater than 1 are common and a value of up to 0.99 has been noted.

According to **Ortel (1961)** the "weighted mean" concentration for a trace element in a soil profile is probably an outcome of pedogenic processes as, it also indicates the original concentration in the parent material **(Oertel, 1961)**. The trend (T) and specific range (R), on the other hand, are an outcome of the pedogenic processes alone (except where the parent material is markedly heterogeneous in trace element contents).

Table 12 presents the above-mentioned statistical measures; i.e. weighted mean (W), trend (T) and specific range (R) for totals of the trace elements Fe, Mn, Zn and Cu in the profiles of studied soils.

4.7.1. Iron (Fe):

Data listed in **Table 12** show that the weighted mean (W) in the soils of Siwa oasis varies widely between 1695 to 22734 mg kg^{-1}. The lowest value is recorded in profile 3 of the Khamisa region soils, while the highest value is found in profile 19 of the Timeira El-Masser region soils with a tendency of increase towards the fine texture.

Values of the trend (T) indicate symmetrical distribution of all of the 8 regions of Siwa Oasis. The specific range (R) of total Fe indicates that in Timeira, soils of profile 19 are of homogeneous materials, while in the other regions they are of heterogeneous materials.

4.7.2. Manganese (Mn):

Table 12 show that the weighted mean (W) of total Mn of soils of Siwa Oasis, ranges between 60 and 4199 mg kg^{-1} in profiles 4 of Khamisa and 14 of Abu-shrouf respectively, with a tendency of increasing towards the fine texture. The values of trend (T) indicates more symmetrical Mn distribution in profiles, 1, 7, 10, 11, 16 and 19 as indicated by their small (T) values. The specific range (R) of Mn indicates that the soils of profiles 7, 11, 14, 15 and 19 are homogeneous, whereas, the other soil profiles are heterogeneous.

4.7.3. Zinc (Zn):

Data listed in **Table 12** show that the weighted mean (W) ranges between 11.0 and 87.1 mg kg^{-1} in profiles 4, of Khamisa, and 19, of Timeira El-Masser region, respectively, with an increase towards the fine texture. Also, the computed trend indicated more symmetrical distribution of Zn in profiles 2, 5, 9, 10, 12, 17 and 19 than in the other soil profiles.

Specific range (R) indicates that the soils display some homogeneity of their material in profiles 5, 10, 12 and 19, while in the other profiles it indicates heterogeneity of the soil materials.

Table 12: Weighted mean (W), Trend (T) and Specific range (R) of total Fe, Mn, Zn and Cu content of soils of Siwa oasis.

Region	Profile No.	Fe			Mn			Zn			Cu		
		W	T	R	W	T	R	W	T	R	W	T	R
	1	2119	0.028	0.191	81	-0.130	0.382	25.1	-0.500	1.658	2.57	-0.250	0.603
EL-Maraqui	2	11514	0.469	1.570	316	0.254	1.217	48.9	0.068	1.266	2.97	-0.250	1.910
	3	1695	-0.241	0.713	140	0.585	1.317	18.3	0.441	0.991	5.08	0.050	0.110
Khamisa	4	2802	-0.294	0.703	60	-0.402	0.889	11.0	-0.243	0.557	3.36	-0.323	0.866
	5	6217	0.270	0.396	281	0.476	0.830	42.7	0.064	0.115	7.10	0.260	0.690
	6	12318	0.558	1.258	244	0.359	0.541	28.8	0.249	0.404	8.84	-0.461	1.324
Siwa	7	5436	0.007	0.145	187	0.053	0.104	86.9	-0.514	1.776	6.10	-0.001	0.389
	8	11548	0.362	1.187	214	0.167	0.348	34.0	0.135	0.201	8.26	-0.042	0.160
	9	11605	-0.310	0.897	254	-0.257	0.691	45.8	-0.090	0.198	9.86	-0.274	0.757
Aghormi	10	1939	-0.132	0.251	67	-0.106	0.211	59.2	0.011	0.020	2.73	-0.040	0.245
	11	2238	0.116	0.250	83	-0.024	0.053	35.1	0.660	1.960	3.23	0.093	0.330
	12	5329	0.027	0.102	318	-0.133	0.310	20.6	-0.037	0.095	3.98	0.030	0.867
Qureishet	13	5870	-0.013	0.059	95	-0.320	0.862	23.1	-0.517	1.581	6.20	-0.474	1.330
	14	12284	0.229	0.699	4199	0.901	0.026	52.6	0.364	1.724	4.44	-0.365	0.872
Abushrouf	15	4413	-0.275	1.182	194	-0.300	0.034	14.3	-0.226	0.780	2.45	-0.271	0.853
	16	14392	0.218	0.889	493	-0.108	0.415	49.9	0.311	1.252	5.58	-0.082	0.219
El-Zeitun	17	8907	0.101	0.303	433	0.116	0.346	43.1	-0.049	0.390	5.46	-0.216	0.557
	18	22060	0.068	0.135	706	0.184	0.368	36.8	0.299	0.599	3.10	-0.240	0.640
Timera	19	22734	0.014	0.019	617	0.021	0.028	87.1	0.079	0.016	3.10	-0.129	0.197

4.7.4. Copper (Cu):

Table 12 show that the weighted mean (W) ranges between 2.45 and 8.84 mg kg^{-1} in profiles 15 of Abu-Shrouf region soils and 6 of Siwa region soils, respectively, with an increase towards the fine texture. The values of trend indicated that total Cu distribution in profiles 3, 7, 8, 10, 11, 12, 16 and 19 is more symmetrical than the other soil profiles. Specific range (R) of total Cu indicates that the homogeneity of their soil material in profiles 3, 8 and 19, while the other profiles are found of heterogeneous soil materials.

4.8. Depthwise distribution of available micronutrients:

4.8.1. DTPA-extractable (Fe):

Data listed in **Table 13** show that the weighted mean (W) in the soils of Siwa Oasis vary between 1.4 to 135.0 mg kg^{-1}. The lowest value was recorded in the profile 17, of the El-Zeitun region soils, while the highest value is found in the profile 5, of the Khamisa region soils. Then in a tendency of increase towards the fine texture. The values of trend (T) indicate more symmetrical Fe distribution in profile 10, of the Aghormi region soils, as indicated by its small (T) value. The specific range (R) of Fe indicates that the soils of profiles 3 and 17 are homogeneous, whereas the other soil profiles are heterogeneous.

4.8.2. Manganese (Mn):

Table 13 show that the weighted mean (W) of DTPA-extractable Mn of soils of Siwa Oasis, ranges between 7.3 to 193.7 mg kg^{-1} in profiles 11 and 5, respectively. There is a tendency of increasing towards the fine texture. The values of trend (T) indicate more symmetrical Mn distribution in profile 1, 7, 9 and 10 as is shown by their small (T) values. The specific range (R) of Mn indicates that the soils of profiles 1, 9 and 10 are homogeneous, whereas other soil profiles are heterogeneous.

4.8.3. Zinc (Zn):

Data listed in **Table 13** show that the weighted mean (W) ranges between 0.55 to 4.33 mg kg^{-1} in profiles 1, of El-Maraqui region soils, and 9, of Aghormi region soils, respectively, with an increase towards the fine texture. The trend (T) indicates more symmetrical distribution of Zn in profiles 3, 4, 11, 14, 16 and 18 than in the other soil profiles. Specific range (R) indicates that the soils show homogeneity of their soil material in profiles 3 and 16, while the other profiles it shows that the soils are of heterogeneous materials.

4.8.4. Copper (Cu):

Table 13 show that the weighted mean (W) ranges between 0.17 and 4.52 mg kg^{-1} in profiles 18, of Timeira El-Masser region soils, and 9, of Aghormi region soils, respectively, with an increase towards the fine texture. The values of trend (T) indicates that available Cu distribution in profiles 4, 6, 9, 10, 12, 15 and 16 are more symmetrical than in the other soil profiles. Specific range (R) of available Cu indicates that the soils homogeneity of their soil material in profiles 9 and 10. In the other profiles it indicates heterogeneous soil materials.

Table 13: Weighted mean (W), Trend (T) and Specific range (R) of DTPA-extractable Fe, Mn, Zn Cu content of soils of Siwa oasis.

Region	Profile No.	Fe			Mn			Zn			Cu		
		W	T	R	W	T	R	W	T	R	W	T	R
EL-Maraqui	1	15.2	-0.47	1.76	10.1	0.09	0.19	0.55	0.16	0.38	0.30	0.17	0.33
	2	65.6	-0.54	1.72	63.3	-0.44	1.51	2.66	-0.34	1.04	3.35	0.71	1.02
Khamisa	3	1.9	-0.20	0.56	43.2	0.78	1.75	0.99	-0.03	0.06	0.95	0.63	1.42
	4	22.3	0.600	1.13	26.4	-0.40	1.09	2.21	-0.08	0.34	0.89	-0.14	0.46
	5	135.0	-0.48	1.62	193.7	0.50	1.09	3.26	-0.12	1.51	2.32	0.55	1.27
Siwa	6	70.8	-0.64	2.65	111.1	0.33	0.51	2.45	-0.46	1.38	1.28	-0.09	0.80
	7	15.2	0.440	1.37	46.1	0.09	0.30	3.59	-0.31	0.73	2.13	-0.38	1.00
Aghormi	8	97.4	-0.65	2.78	94.4	0.75	1.48	2.16	-0.52	1.70	0.53	0.64	0.96
	9	20.2	0.72	1.44	84.8	0.06	0.13	4.33	-0.20	0.51	4.52	0.01	0.01
	10	31.9	0.08	0.87	8.1	0.05	0.14	1.43	-0.53	1.69	0.19	0.11	0.16
	11	47.6	0.59	1.34	7.3	-0.23	0.47	0.59	-0.08	0.27	0.46	0.54	1.70
Qureishet	12	8.7	0.40	1.38	144.7	-0.16	0.42	1.82	-0.19	0.48	0.58	0.12	0.29
	13	9.1	-0.67	2.84	10.6	-0.12	0.22	0.42	0.12	0.88	0.73	-0.62	2.37
Abu-Shrouf	14	6.3	-0.16	1.18	85.6	-0.14	0.30	1.81	-0.02	0.65	0.77	0.14	0.25
	15	20.1	-0.45	1.15	55.8	0.18	0.41	2.61	-0.22	0.77	0.73	0.01	0.18
EL-Zeitun	16	2.6	0.47	0.78	110.3	-0.18	0.39	1.24	-0.04	0.09	1.03	-0.14	0.28
	17	1.4	-0.14	0.27	140.5	0.28	0.48	1.47	-0.27	0.67	1.53	0.27	0.57
Timeira	18	22.6	-0.43	1.52	20.8	-0.35	1.06	0.86	0.02	0.05	0.17	-0.58	1.12
	19	29.2	-0.46	1.13	18.6	-0.43	1.01	0.56	-0.22	0.38	0.41	-0.32	0.61

4.9. Amorphous materials (silica and sesquioxides), (Table 14):

The obtained data of amorphous materials for the studied soils **(Table 14)** show that silica (SiO_2) content varies widely from 0.20 to 26.21 % with an average of 11.66 %. The lowest content is in the (0–45 cm) surface layer of profile 9, of the Aghormi region soils, while the highest content is observed in the (55–90 cm) sub-surface layer of profile 16, of the El-Zeitun region soils. On the other hand, alumina (Al_2O_3) content in the studied soil ranges from 0.15 % to 4.40 % with an average of 0.81 %. The lowest value is found in the sub-surface layer (45–60 cm) of profile 12, in the Qureishet region soils, while the highest value is recorded in the (90–150 cm) deepest layer of profile 4, in the Khamisa region soils.

The contents of Fe_2O_3 range between 5.09 % and 42.70 % with an average of 12.95 %. The lowest content is found in the surface layer (50–90 cm) of profile 10, in the Aghormi region soils, while the highest content is found in the sub-surface layer (25–50 cm) of profile 18, in the Timeira El-Masser region soils. Also, data show that MnO content range between 0.08 % and 2.30 % with an average of 0.50 %. The lowest content is found in the deepest layer (70–150 cm) of profile 13, in the Qureishet region soils, while the highest content is found in the deepest layer (80–150 cm), of profile 5 in the Khamisa region soils.

Table 14: Amorphous material contents of soils of Siwa oasis.

Region	Profile No.	Depth (cm)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	Total (%)	SiO_2/Al_2O_3 Molar- ratio	SiO_2/Fe_2O_3 Molar- ratio	SiO_2/MnO Molar- ratio
EL-Maraqui	1	0 – 60	6.17	1.53	5.78	0.18	13.66	5.15	2.86	41.2
		60 -90	6.84	3.15	6.68	0.21	16.88	3.6	2.71	37.9
		90 - 150	7.23	0.69	7.02	0.23	15.17	17.6	2.73	37.5
	2	0 - 30	11.63	0.43	12.36	0.91	25.33	45.2	2.52	15.8
		30 - 60	13.43	0.73	14.36	0.93	29.45	30.6	2.49	16.9
		60 -90	19.35	0.40	24.20	0.96	44.91	82.1	2.12	24.6
		90 - 150	9.76	0.41	11.95	0.38	22.50	40.0	2.16	29.6
Khamisa	3	0 -50	10.37	1.61	17.39	0.75	30.12	8.5	1.59	15.45
		50 -90	21.05	0.48	27.74	0.84	50.11	87.5	2.01	31.8
	4	0 - 60	10.22	0.57	7.24	0.28	18.31	34.0	3.78	43.6
		60 -90	8.29	2.71	8.18	0.34	19.52	4.7	2.71	29.2
		90 - 150	8.87	4.40	8.69	0.52	22.48	3.8	2.74	20.5
	5	0 -40	19.06	0.36	21.48	0.75	41.65	91.4	2.35	32.0
		40 -80	17.34	0.38	9.37	1.20	28.29	96.4	4.90	14.5
		80 -150	19.03	0.17	15.02	2.30	36.52	188.2	3.37	10.7
Siwa	6	0 - 30	15.59	0.45	15.74	0.70	32.48	59.1	2.62	26.3
		30 - 60	16.90	0.27	17.36	0.72	35.25	107.7	2.58	28.0
		60 -90	19.85	0.31	20.28	0.80	41.24	106.5	2.60	33.0
	7	0 -55	7.70	0.72	14.21	0.39	23.02	18.3	1.44	23.6
		55 -75	4.61	1.49	11.72	0.37	18.19	5.3	1.05	15.4
		75 -150	12.30	3.90	14.33	0.43	30.19	5.0	2.28	32.8
Aghormi	8	0- 45	11.03	0.99	10.30	0.49	22.81	18.6	2.83	26.0
		45 -85	14.05	2.40	12.96	0.38	29.79	9.6	2.89	42.6
		85 -150	6.79	0.34	11.83	0.34	19.30	33.3	1.53	22.9
	9	0 -45	0.20	0.27	10.07	0.45	10.99	1.5	0.05	0.48
		45 -90	1.20	0.47	12.45	0.39	14.51	5.0	0.26	3.6
	10	0 -50	3.96	1.32	5.72	0.14	11.14	5.4	1.83	36.8
		50 -90	4.06	0.42	5.09	0.15	9.72	19.5	2.13	38.1
		90 -150	7.07	0.67	5.86	0.16	13.76	20.0	3.19	52.2

Table 14: Cont.

Region	Profile No.	Depth, (cm.)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	Total (%)	SiO_2/Al_2O_3 Molar- ratio	SiO_2/Fe_2O_3 Molar- ratio	SiO_2/MnO Molar- ratio
Aghormi Cont.	11	0 -45	9.70	0.24	5.86	0.18	15.87	66.7	4.47	64.0
		45-95	3.41	1.22	5.17	0.13	9.93	5.0	1.78	33.3
		95 -150	3.17	0.76	6.70	0.24	10.87	6.7	1.26	16.7
Qureishet	12	0-45	16.50	0.37	9.71	0.27	26.85	75.0	4.51	71.1
		45-60	18.07	0.15	7.20	0.57	25.99	200.0	6.67	37.5
		60-100	20.18	0.21	6.70	0.60	27.69	161.9	8.00	40.0
	13	0-45	11.10	0.50	4.86	0.13	16.59	36.7	6.17	100..0
		45-70	10.10	0.36	5.99	0.11	16.56	48.6	4.42	106.3
		70-150	9.54	0.17	3.86	0.08	13.65	94.1	6.63	145.5
Abu-Shrouf	14	0-45	13.94	0.39	16.79	0.67	31.79	60.5	2.21	25.6
		45-95	15.05	0.21	15.91	0.64	31.81	119.0	2.53	27.78
		95-150	20.19	0.34	15.57	0.26	36.36	103.0	3.43	91.9
	15	0-35	15.6	0.91	12.16	0.42	29.09	29.2	3.42	44.1
		35-85	16.23	0.50	8.89	0.09	25.71	55.1	4.82	207.7
		85-150	13.63	0.67	10.01	0.78	15.09	34.8	3.60	23.0
EL-Zeitun	16	0-55	16.57	0.27	9.05	0.50	26.39	107.7	4.84	40.0
		55-90	26.21	0.26	17.27	0.72	44.46	169.2	4.04	44..0
		90-150	23.34	0.44	10.20	0.60	34.58	90.7	6.06	45.9
	17	0-55	7.80	0.50	12.37	0.76	21.43	26.5	1.69	13.0
		55-85	13.35	0.65	10.44	0.70	25.14	34.4	3.36	22.22
		85-130	21.29	0.32	11.91	0.33	33.85	112.9	4.72	74.5
Timera	18	0-25	0.40	0.29	28.23	0.38	29.30	2.14	0.02	1.11
		25-50	0.53	0.39	42.70	0.14	43.76	2.1	0.03	4.2
	19	0-10	1.16	0.62	25.96	0.56	28.30	3.3	0.12	2.5
		10-40	8.87	0.99	30.17	0.37	40.40	15.5	0.78	28.8

Considering content of total amorphous materials (silica, alumina, iron and manganese oxides) in the studied soils results show that such total contents range between 9.72 % and 50.11 % with an average of 25.72 %. The lowest content in the (50-90 cm) sub-surface layer of profile 10 of the Aghormi region soils, while the highest content is observed in the (50-90 cm) sub-surface layer of profile 3 of the Khmisa region soils. Indicating that the degree of weathering of the parent material was very high in these soils. **Jackson (1965)** mentioned that the content of amorphous materials is related to the degree of weathering and that up to 5 % of amorphous materials indicate low weathering, whereas from 5 to 14 % indicates moderate weathering and more than 14 % indicates high weathering.

Concerning the silica/ alumina ratio (SiO_2/Al_2O_3), Silica/ iron oxide ratio (SiO_2/Fe_2O_3) and silica / manganese oxide ratio (SiO_2/MnO) results show that SiO_2/Al_2O_3 varies between 1.50 to 200, with an average of 52.12. The lowest was in the (0–45 cm) surface layer of profile 9 of the Aghormi region soils, while the highest was in the (45-60cm) sub surface layer of profile 12 of the qureishet region soils. The ratio of SiO_2/Fe_2O_3 varies between 0.02 to 8.0 with an average of 2.92. The lowest was in the (0–25 cm) surface layer of profile 18 of the Timeira El-Masser region soils, while the highest was in the (60–100 cm) deepest layer of profile 12 of the Qureishet region soils. The ratio of SiO_2/MnO varies between (0.48 to 207.7) with an average of 38.77 The lowest was in the (0–45 cm) surface layer of profile 9 of the Aghormi region soils, while the highest was in the (35–85 cm) sub-surface layer of profile 15 of the Abu-Shrouf region soils.

Low amorphous materials in the soil indicate some degree of mineral degradation and weathering during the pre-wet climatic conditions despite the high resistance of minerals in the soil parent material, and despite the aridity of the region. According to **Mackenzie (1967)**, SiO_2/Fe_2O_3 ratio is extremely low i.e. < 0.04 in sediments derived from basic igneous rocks and is high i.e. > 4.0 in deposits derived from acidic alkaline igneous rocks.

4 .10: Cations exchange capacity (CEC), surface area of soil separates of clay, silt, and fine sand (Table 15):

4.10.1. Clay size (< 0.002 mm Ø):

Data tabulated in **Table 15** show that cation exchange capacity (CEC) of the clay fraction varies widely between the studied soils and range from 19.5 to 83.0 $cmol_c$/kg clay with an average of 48.19 $cmol_c$/kg clay. The lowest value is found in the sub-surface (45–85 cm) layer of profile 8 in the Aghormi region soils. The highest value is in the deepest (10 – 40 cm) layer of profile 19 in the Timeira El-Maasser region soils. Surface area of the clay ranges between 838 and 922 m^2/g clay with an average of 887 m^2/g clay. The lowest value is recorded in the surface (0 – 45 cm) layer of profile 5 of the Khamisa region soils, while the highest value is found in the deepest (90 – 150 cm) layer of profile 2 of the El-Maragui region soils.

Table 15: Cations exchange Capacity (CEC); surface area of soil separates (clay, silt, and fine sand) of Siwa oasis.

Region	Profile No.	Depth, (cm.)	Soil separates					
			Clay <0.002 mm		Silt 0.02-0.002 mm		Fine Sand 0.2-0.02 mm	
			CEC $cmol_c/kg$	Surface area m^2/g	CEC $cmol_c/kg$	Surface area m^2/g	CEC $cmol_c/kg$	Surface area m^2/g
El- Maraqui	2	0 - 30	43.5	909	35.0	856	4.4	61
		30 - 60	56.5	886	28.5	850	6.0	61
		60 -90	58.5	902	39.0	860	4.0	60
		90 - 150	67.5	922	51.0	839	4.0	59
Khamisa	5	0 - 40	67.5	838	35.0	840	3.6	60
		40 - 80	65.0	888	50.0	859	6.0	60
		80 - 150	67.5	892	21.5	800	4.4	64
Siwa	6	0 -30	39.0	880	33.5	798	4.4	61
		30 -60	50.0	905	45.5	823	3.5	60
		60 - 90	33.5	910	23.0	861	5.2	60
Aghormi	8	0 - 45	40.0	908	24.0	820	7.4	63
		45 - 85	19.50	865	17.5	846	6.6	61
		85 - 150	23.0	871	17.5	777	7.8	61
Qureishet	12	0 - 45	28.5	906	17.0	855	5.2	59
		45 - 60	57.5	854	26.0	796	7.8	58
		60 - 100	28.5	858	16.5	839	8.1	68
Abushrouf	14	0 - 45	40.0	880	27.0	806	7.4	62
		45 - 95	52.0	906	27.0	848	4.0	62
		95 - 150	57.5	877	28.5	817	7.0	62
El -Zeitun	17	0 - 55	57.5	888	39.0	810	7.4	61
		55 - 85	50.0	874	27.0	796	5.2	61
		85 - 150	36.0	888	27.0	792	6.0	61
Timeira	19	0 - 10	35.0	878	27.0	800	5.2	59
		10 - 40	83.0	894	14.0	839	3.4	59

4.10.2. Silt size (0.02 – 0.002 mm Ø):

Data in **Table 15** show that cation exchange capacity (CEC) of the silt fraction varies widely between the studied soils and ranges from 14.0 to 51.0 $cmol_c/kg$ silt with an average of 29.0 $cmol_c/kg$ silt. The lowest value is found in the deepest (10 – 40 cm) layer of profile 19 in the Timeira El-Maasser region soils, while the highest value is in the deepest (90 – 150 cm) layer of profile 2 of the Aghormi region soils. Surface area of silt ranges between 777 and 861 m^2/g silt with an average of 826 m^2/g silt. The lowest value is recorded in the deepest (85 – 150 cm) layer of profile 8 of the Aghormi region soils, while the highest value is found in the deepest (60 – 90 cm) layer of profile 6 of the Siwa region soils.

4.10.3. Fine sand (0.2 – 0.02 mm Ø):

Data in **Table 15** show that cation exchange capacity (CEC) of fine sand fraction values varies widely between the studied soils and range from 3.4 to 8.1 $cmol_c/kg$ fine sand with an average of 5.6 $cmol_c/kg$ fine sand. The lowest value is found in the deepest (10 – 40 cm) layer of profile 19 in the Timeira El-Maasser region soils, while the highest value is in the deepest (60–100 cm) layer of profile 12 of the Qureishet region soils. Surface area of fine sand fraction ranges between 58 and 68 m^2/g fine sand with an average of 58.42 m^2/g fine sand. The lowest value is recorded in the sub-surface (45 – 60 cm) layer of profile 12 of the Qureishet region soils, while the highest value is found in the deepest (60 – 100 cm) layer of profile 12 of the Qureishet region soils.

4.11. Mineralogy of the very fine sand fraction (Tables 16 and 17):

Mineralogy of the very fine sand fraction (the 0.125-0.063 mm **Ø** fraction) helps in evaluating profile uniformity and development, as well as soil genesis and weathering sequence losses and gains. It also helps in predicting the major process involved in the soil formation. Heavy minerals are either inherited from the parent material or formed as products during the course of soil formation. **Buckhamman and Ham (1942) and Haseman and Marshall (1945)** stated that the origin of the soil is assessed according to the kind, and the type of frequency distribution of heavy minerals. **Pettijohn (1941) and Weyl (1952)** listed the heavy minerals in an order according to their resistance to weathering; and **Brewer (1955)** used the notion of index minerals "i.e.residual minerals" to evaluate soil profile uniformity. **Barshad (1955), Brewer (1964) and Chapman and Horn (1968)** suggested using the ratios between two or more of the ultra-stable minerals as indicators for uniformity evaluation, some of these ratios were used for evaluation of some soils of Egypt **(Hammad, 1968; El-Kady, 1970; El-Demerdash, 1970; Mitchell, 1975; Abdel Aal et al, 1977; Kasem, 1977; Shata, 1978; El-Demerdash et al, 1979; El-Shazly, 1983 and Bahnasawy, 2002).Tables 16 and 17** show the frequency distribution of sand (very fine sand of the 0.125-0.063 mm Ø) minerals in soils of the current study. The minerals are distinguished into "light" and "heavy" minerals. The heavy minerals are further distinguished into "opaque" and "non-opaque" minerals.

Table 16: Relative abundance (100 maximum) of light minerals in the very fine sand fraction (0.125- 0.063 mm) of soils of Siwa oasis.

Region	Profile No.	Depth, cm	Quartz %	Feldspars %			Total %
				Orthoclase	Plagioclase	Microcline	
EL-Maraqui	2	0-30	97.00	1.00	1.00	1.00	3.00
		30-60	96.00	1.50	1.00	1.50	4.00
		60-90	95.00	1.50	1.50	2.00	5.00
		90-150	95.00	1.50	2.00	1.50	5.00
Khamisa	5	0-40	93.50	1.50	2.00	3.00	6.50
		40-80	95.50	1.50	2.00	1.00	4.50
		80-150	95.00	2.00	1.50	1.50	5.00
Siwa	6	0-30	96.00	1.50	1.00	1.50	4.00
		30-60	94.00	2.00	2.50	1.50	6.00
		60-90	94.50	1.50	2.00	1.00	4.50
Aghormi	8	0-45	94.00	2.00	2.00	2.00	6.00
		45-85	93.50	2.00	2.50	2.00	6.50
		85-150	95.00	2.00	1.50	1.50	5.00
Qureishet	12	0-45	95.00	2.00	1.50	1.50	5.00
		45-60	94.00	2.00	2.00	2.00	6.00
		60-100	93.00	1.50	2.00	3.50	7.00
Abu-shrouf	14	0-45	94.50	1.50	2.00	2.00	5.50
		45-95	95.00	2.00	1.50	1.50	5.00
		95-150	94.00	2.00	2.00	2.00	6.00
EL-Zeitun	17	0-55	94.00	2.00	1.50	2.50	6.00
		55-85	95.00	1.50	1.50	2.00	5.00
		85-150	95.00	1.50	2.00	1.50	5.00
Timeira	19	0-10	94.50	2.00	2.00	1.50	5.50
		10-40	95.00	2.00	1.50	1.50	5.00

4.11.1. Light minerals (Table 16):

Table 16 shows the frequency distribution of light minerals of the specific gravity [SP. gr. < 2.85 g/cm^3 **(Carver, 1971)**]. These minerals were almost entirely quartz (> 93.0 % of the minerals). Depth wise distribution of quartz did not portray any specific pattern. Feldspars were detected in all soils. They are composed essentially of three members, namely orthoclase, plagioclase and microcline.

Orthoclase grains are colorless, partially cloudy with a low relief, sometimes displaying simple twinning. Plagioclase grains display a lamellar twinning and polysynthetic quardraline structure. The lowest value is in profile 12 of the Qureishet region soils, while the highest value is in profile 2 of the El-Maraqui region soils, while the order of abundance was: microcline > plagioclase > orthoclase.

4.11.2. Heavy minerals:

Heavy minerals are those which have specific gravity >2.85 g/cm^3 **(Carver, 1971)** and are usually of primary origin. Although they may be present in small contents, they play an important role in soil formation and development. Several authors **(Hammad, 1968; El-Kadi, 1970; Mitchell, 1975 and Bhanasawy, 2002)** emphasized the importance of the dominant heavy minerals in assessing soil genesis

I. Opaque heavy minerals:

The majority of heavy minerals of the current study are opaques. Opaque minerals are frequently associated with a transparenting of the rock forming minerals **(Kerr, 1959)**; they have higher specific gravity than the non-opaques because of their iron content **(Folk, 1968)**.

Table 17 shows that opaque minerals range between 36.86 and 62.50 % of the heavy minerals with an average of 45.97 %. The lowest value is in profile 6 of the Siwa region soils, the highest is in profile 8 of the Aghormi region soils. The vertical distribution of opaque minerals shows an irregular pattern.

II. Non-opaque heavy minerals:

Table 17 shows that the comparatively weatherable minerals (the pyroboles i.e. pyroxenes and amphiboles) as well as the ultastable minerals (zircon, rutile and tourmaline) are the most abundant varieties in the non-opaques. Parametamorphic minerals (garnet, kyanite, staurolite, silimanite and andalusite minerals) are in low frequency distribution while the apatite is in lower to negligible content.

A: The pyroboles:

They are the most important group of the non-opaques and include the amphiboles and the pyroxenes; the latters are more abundant and are easily weatherable than the formers.

The amphiboles, $Ca(Mg, Fe, Al)_5(OH)_2[(Si, Al)_4O_{11}]_2$ or $Ca\ (Mg, Fe)_5(OH)_2(Si_4O_{11})_2$, are the most important group in the pyroboles. They constitute from 8.11 to 19.23 % of the non-opaques with an average of 12.21 %. The lowest value is in the deepest (85 – 150 cm) layer of profile 8 of the Aghormi region soils, while the highest value is in sub-surface (45 – 60 cm) layer of profile 12 of the Qureishet region soils. According to **Keer (1959)** hornblende

Table 17: Relative abundance i.e.frequency distribution (100 maximum) of heavy minerals in the very fine sand fraction (0.125-0.063mmØ fraction) of soils of Siwa oasis.

Region	Profile No.	Depth (cm)	Opaque %	Non -Opaque %	Frequency distribution of the non-opaque																Index figure %
					Pyroboles		Epid-ote %	Biotte %	Para metamorphic %					Glau-Conite %	Mona-zite %	Ultra stable %			Apatite %	Others %	
					Amphiboles %	Pyroxenes %			Gar-net	Kyanit-e	Stauro-lite	Sillma-nite	Andal-usite			Rutile	Tour – maline	Zircon			
El-Maraqui	2	0-30	38.46	61.54	14.67	19.02	2.72	7.07	2.72	1.63	2.72	1.63	1.63	2.17	0.00	8.15	3.27	29.89	1.09	1.62	0.72
		30-60	42.11	57.89	9.09	11.52	4.24	3.03	4.85	1.21	3.03	3.03	3.03	3.03	1.21	9.09	4.85	36.36	1.21	1.22	2.27
		60-90	41.38	58.62	10.57	11.76	4.71	2.35	2.94	1.18	4.12	2.35	2.94	1.18	0.00	10.59	5.88	38.23	0.00	1.2	2.17
		90-150	41.79	58.21	9.74	10.26	2.56	6.67	4.10	1.54	5.13	2.56	2.56	1.54	0.50	10.26	5.13	35.90	0.00	1.55	2.28
Khamisa	5	0-40	45.60	54.40	11.98	16.77	5.99	4.79	2.99	0.60	4.20	2.99	2.99	0.00	0.00	8.38	3.59	32.93	0.00	1.80	0.40
		40-80	48.54	51.46	10.69	12.58	6.29	3.14	3.14	1.89	5.03	3.14	4.40	0.00	1.26	10.06	5.66	31.45	0.00	1.27	1.41
		80-150	43.54	56.46	9.04	13.30	1.60	1.60	4.26	2.13	4.26	3.72	4.26	0.00	0.00	12.23	5.32	37.23	0.00	1.05	2.19
Siwa	6	0-30	44.16	55.84	12.43	16.95	1.13	5.08	2.26	1.70	4.52	2.82	3.95	0.00	0.00	7.91	5.65	33.90	0.00	1.70	1.00
		30-60	36.86	63.14	9.14	10.15	2.54	2.03	2.54	2.03	4.06	2.54	3.55	0.00	0.00	14.72	7.61	38.07	0.00	1.02	1.20
		60-90	44.12	55.88	12.11	15.79	2.63	2.11	2.63	1.58	3.68	3.16	3.68	0.00	0.00	10.53	6.84	34.21	0.00	1.05	1.04
Aghormi	8	0-45	44.16	55.84	12.99	10.73	2.82	2.82	2.26	1.69	3.95	2.85	3.95	0.00	0.00	11.30	5.08	36.72	1.13	1.71	1.01
		45-85	62.50	37.50	11.73	11.73	2.55	4.59	3.57	4.59	5.10	4.08	4.08	0.00	0.00	10.20	5.10	30.61	1.02	1.05	1.68
		85-150	44.78	55.22	8.11	10.82	1.08	4.32	3.78	2.70	5.40	3.78	4.86	0.00	0.00	10.27	4.32	39.46	0.00	1.1	0.79
Qureishet	12	0-45	48.20	51.80	9.88	13.37	0.58	1.74	2.91	1.16	2.91	2.33	3.49	0.00	0.00	12.79	4.65	43.60	0.00	0.59	1.58
		45-60	49.72	50.28	19.23	19.23	2.20	2.75	2.75	2.20	2.75	2.75	2.75	0.00	0.00	8.24	3.85	30.22	0.00	1.08	2.29
		60-100	50.93	49.07	11.32	11.32	1.89	2.52	1.26	2.52	3.14	3.14	3.14	0.00	0.00	12.58	6.29	40.88	0.00	0.00	1.84
Abushrouf	14	0-45	45.59	54.41	10.81	11.89	2.70	2.16	3.78	2.16	5.41	3.24	4.85	0.00	0.00	5.41	8.11	37.84	0.00	1.64	0.65
		45-95	42.17	57.83	15.63	11.98	1.56	7.81	2.60	1.56	4.17	2.08	3.65	0.00	0.00	9.90	4.17	33.85	0.00	1.04	0.82
		95-150	46.23	53.77	15.00	14.05	3.18	1.91	3.18	2.55	4.46	1.91	3.18	0.00	0.00	11.11	4.46	33.76	0.00	1.25	1.12
El-Zeitun	17	0-55	45.59	54.41	12.29	13.40	2.23	3.91	5.03	2.23	5.03	2.79	4.47	0.00	0.00	10.61	5.03	32.96	0.00	0.02	0.80
		55-85	47.55	52.45	16.37	14.04	2.34	1.75	5.26	2.34	4.68	2.92	4.68	0.00	0.00	8.19	4.09	32.16	0.00	1.18	0.20
		85-150	51.67	48.33	14.47	10.69	1.26	0.63	4.40	1.89	4.40	2.52	3.14	0.00	0.00	9.43	5.03	40.88	0.00	1.26	0.48
Timeira	19	0-10	46.15	53.85	14.29	11.43	2.86	2.29	5.71	2.29	4.57	2.86	4.00	1.14	0.57	5.71	5.71	34.29	0.00	2.28	1.00
		10-40	51.40	48.60	11.54	11.54	2.42	3.21	5.13	3.21	3.21	1.92	2.42	0.84	1.92	8.97	6.41	35.26	0.00	2.0	2.04

is the main mineral of the amphiboles, while glucophane and actinolite are the minor minerals. Hornblendes are sub-angular to subrounded prismatic crystals, in two varieties dominated by light green with few brown types, both with strong pleochrism and are common in igneous rocks **(Kerr, 1959)**. In the current study, the vertical distribution of pyroboles (amphiboles and pyroxenes) showed no regular pattern. Since amphiboles and pyroxenes are easily weathered, their high content in soil indicates immature conditions and recent deposition.

The pyroxenes, Ca (Mg), Fe $(SiO_3)_2[(Al, Fe)_2O_3]_x$, are subrounded grains representing the greenish yellow, green, brownish and colorless varieties **(Kerr, 1959)**. They constitute from 10.15 to 19.23 % of the non-opaques with an average of 13.10 %. The lowest is in the subsurface (30 – 60 cm) layer of profile 6 of the Siwa region soils, and the highest is in the subsurface (45 – 60 cm) layer of profile 12 of the Quresishet region soils. Augite is common member in this family, while minerals like hyperthene and diopside constitute subordinate amounts. Augite is a very common minerals in subsilicic igneous rocks, **(Kerr, 1959)**

B: Epidotes and biotites:

The epidotes, Ca_2Al_3 (OH) $(SiO_4)_3$ are angular to sub-angular generally yellow anisotropic, highly plethoric having parallel extinction **(Milner, 1962)**. They also include zoisite, clinozoisite, piemontite and allanite **(Deer et al. (1985)** constitutes 0.58 to 6.29 % of the non-opaques with an average of 2.67 %. The lowest is in surface (0 – 45 cm) layer of profile 12 of the Qureishet region soils, while the highest is in the subsurface (40-80 cm) layer of profile 5 of the Khamisa region soils. Soils of recent origin which are derived from igneous and metamorphic rocks are generally higher in biotite minerals compared with those derived from sedimentary rocks **(El-Sheshtawi, 1984)**.

The biotites, K_2 (Mg, Fe)$_2$(OH)$_2$(Al Si_3O_{10}), are iron-rich tri-octahedral dark coloured minerals **(Deer et al. 1985).**

Their presence in soils of the current study range from 0.63 to 7.81 % with an average of 3.35 %. The lowest is in the deep (85-150 cm) layer of profile 17 of the El-Zeitun region soils, while the highest is in the subsurface (45 – 95 cm) layer of profile 14 of the Abu-Shrouf region soils.

C: The parametamorphics:

These minerals include **garnets, kyanites, staurolites, sillimannites and andalusites** they are stable to slightly stable minerals.

Garnets, Fe_3 Al_2(Si O_4)$_3$, are colorless, sometimes pale reddish, euhedral crystals in six to eight sided sections having very high relief **(Milner, 1962)**. In the current study, garnets constitute between 1.26 to 5.71 % of the non-opaques with an average of 3.50 %. The lowest is in the deepest (60 – 100 cm) layer of profile 12 of the Qureishet region soils, while the highest is in the surface (0 – 10 cm) layer of profile 19 of the Timeira El-Maassar region soils.

Kyanites, Al_2 Si O_5, are colorless elongated platy crystals, with two perfect cleavage sets **(Milner, 1962)**. Data in **Table 17** shows that kyanites constitute between 0.6 to 4.59 % of the non-opaques with an average of 2.02 %. The lowest value is in the surface (0 – 40 cm) layer of profile 5 of the Khamisa region soils, while the highest is found in the subsurface (45 – 85 cm) layer of profile 8 of the Aghormi region soils.

Staurolites, $2Al_2$ Si O_5 Fe (OH) $_2$, are sub-angular grains, sometimes prismatic having strong pleochrism and almost stained with inclusions **(Milner, 1962)**. Staurolites of soils of the current study show a distribution of between 2.72 and 5.41 % with an average of 4.16 % of the non-opaques. The lowest is in the surface (0 – 30 cm) layer of profile 2 of the El-Maraqui region soils, while the highest is in the surface (0 -45 cm) layer of profile 14 of the Abu-Shrouf region soils.

Silimanites, $Al_2O_3.SiO_2$, are colorless and cylinder prismatic crystals and in a mass of fibers, and along with staurolites they are found in geniuses, schists and other metamorphic rocks **(Kerr, 1959)**. Soils of current study show that silimanites constitute between 1.63 and 4.08 % of the non-opaques with an average of 2.80 %. The lowest is in the surface (0 – 30 cm) layer of profile 2 of the El-Maraqui region soils, while the highest is in the subsurface (45 – 85 cm) layer of profile 8 of the Aghormi region soils.

Andalusites, $Al_2O_3.SiO_2$. (Fe or Mn), are colourless, sub-angular, rather irregular and rarely prismatic **(Milner, 1962)**. In soils of the current study, andalusites constitute 1.63 to 4.86 % of the non-opaques with an average of 3.57 %. The lowest is in the surface (0 – 30 cm) layer of profile 2 of the El-Maraqui region soils, while the highest is in the deepest (85 – 150 cm) layer of profile 8 of the Aghormi region soils. These are observed in few samples of some profiles. These results are in agreement with those of **Fanous (1979)**.

D: Glauconite and monazite:

Glauconite, SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, K_2O,

H_2O; KMg (Fe, Al) $_3$ Si_8 $O_{18}.3H_2O$ is rounded or irregular grains of certain sediments.These accessory minerals are detected in minute amounts and most of profiles absent.

Monazite, (Ce, La, Di)$_2O_3.P_2O_5$.some $ThO_2.SiO_2$. Monazite is usually occurring as well rounded, pale yellow grains with dark border. It is accessory minerals, is detected in minute amounts and most of profiles absent.

E: Ultrastable minerals:

The ultrastable minerals include rutiles, tourmalines and zircons.

Rutile, TiO_2, rutiles are rounded sub-angular grains; constitute from 5.41 to 14.72 % of the non-opaques with an average of 9.86 %. The lowest is in the surface (0 – 45 cm) layer of profile 14 of the Abu-Shrouf region soils, while the highest is in the subsurface (30 – 60 cm) layer of profile 6 of the Siwa region soils.

Tourmaline, Na (Fe_3 or Mg_3) B_3Al_3 (OH) $_4$($Al_3Si_6O_{27}$); tourmalines are mostly prismatic and subrounded grains exhibiting strong pleochrism and pink rose, brown and green color **(Kerr, 1959)**. They constitute from 3.27 to 8.11 % of the non-opaques with an average 5.25 %. The lowest is in the surface (0–30 cm) layer of profile 2 of the El-Maraqui region soils, while the highest is in the surface (0–45 cm) layer of profile 14 of the Abu-Shrouf region soils.

Zircon (Zr Si O_4); zercones are colorless to pale crystals short prismatic **(Kerr 1959);** constitute from 29.89 to 43.60 % of the non-opaques with an average 35.44 %. The lowest is in the surface (0–30 cm) layer of profile 2 of the El-Maraqui region soils, while the highest is in the surface (0 – 45 cm) layer of profile 12 of the Qureishet region soils.

Omran (2002) found that ultrastable minerals (rutile, tourmaline and zircon) were present in high distribution frequency in some Egyptian soils. Zircon is a widely distributed mineral in granite and other igneous rocks and occurs in some metamorphic rocks, while rutile is widely found in various metamorphic rocks and occasionally in igneous rocks, and tourmaline is found in tourmalinized garnets **(Kerr, 1959)**.

F: The apatite and other minerals:

Apatite, $3Ca_3$ $(PO_4)_3$ CaFe, which is colorless with elongated prismatic grains (and sometimes includes minute iron oxides) has moderate relief, parallel extinction (and may show cleavage parallel to crystal length) is observed in few profiles.

Others minerals constitute from 0.02 to 2.28 % of the non-opaques with an average 1.24 %.The lowest is in the surface (0 – 55 cm) layer of profile 17 of the El-Zeitun region, while the highest is in the surface (0 – 10 cm) layer of profile 19 of the Timeira El-Maassar region soils.

G: The index figures (IF):

The data in **Table 17** show that the index figure is relatively low in most of the studied profiles, and ranges between 0.20 and 2.29 with no specific pattern with depth. The index figures are different from one layer to another, indicating a multi-depositional region. **Gindy (1972)** used the index figure as a criterion for determination of the degree of uniformity of soil parent material (since each sedimentary layer has a characteristic index figure) and considered such parameter as the first step for evaluating development of the soil profile.

The sandy soils of the current study have the highest index figure, while the clayey soils have the low ones. Variations in the index figure values indicate variations in the source of parent material, e.g. sandstone parent materials of Moghra formation which lies in the south of Siwa, and the shale parent material of Marmarica formation. The index figures in the calcareous soil indicate that their parent materials are calcium carbonate materials such as limestone and/or marl, both of which are widely spread in Siwa. The low values of the index figure of Siwa soils indicate that these soils were derived from rocks of the Miocene as stated by **Pettijohn (1941 and 1969)** who reported that index value of 5 indicates an early palaezoic era and that a rise of this value to 17 indicates a more increases in the age of one.

4.11.3. Genesis of soils:

Assemblage of heavy minerals can give useful indications of soil formation. Certain heavy minerals, such as garnet, epidote, staurolite are mainly derived from metamorphic rocks whereas others such as rutile and tourmaline, are derived from igneous rocks **(Tucker, 1981)**.

Data of the current study indicate that resistant minerals (the extremely stable and the stable ones) are present in high contents followed by the widespread minerals (the extremely unstable and the slightly stable ones) indicating that the soils were derived mainly from weathering of igneous and metamorphic rocks.

4.11.4. Uniformity of soil parent materials:

Pyroboles, rutile, tourmaline and zircon, are useful tools for evaluating weathering and soil profile uniformity. Pyroboles are easily weatherable minerals, while rutile, tourmaline and zircon are highly resistant minerals to weathering **(Brewer, 1964)**. Therefore, the presence of easily weatherable minerals in high frequency distribution indicates a young soil. The mineral assemblage as well as the ratios of easily weatherable to highly resistant minerals helps in evaluating profile uniformity. Data of **Table 18** show that most of the soils of the current study of the 8 regions of Siwa are young. Soils show stratification and heterogeneity of their parent materials, which indicates multi-depositional regimes. **Omran (2002)** concluded that Siwa soils are heterogeneous in their depositional regimes.

Table 18: Mineral ratios and weathering ratios calculated from the heavy mineral analysis of the very fine sand fraction (0.125-0.063 mm Ø) soils of Siwa oasis.

Region	Profile No.	Depth, (Cm.)	Minerals ratios *			Weathering ratios *		
			Z/R	Z/T	Z/R+T	Wr1	Wr2	Wr3
El-Maraqui	2	0-30	3.67	9.14	2.62	1.02	0.44	0.21
		30-60	4.00	7.50	2.61	0.50	0.22	0.07
		60-90	3.61	6.50	2.32	0.51	0.24	0.05
		90-150	3.50	6.99	2.33	0.49	0.24	0.16
Khamisa	5	0-40	3.93	9.17	2.75	0.79	0.33	0.13
		40-80	3.13	5.56	2.00	0.63	0.29	0.08
		80-150	3.04	7.00	2.12	0.53	0.21	0.04
Siwa	6	0-30	4.29	6.00	2.50	0.74	0.31	0.13
		30-60	2.59	5.00	1.70	0.42	0.20	0.04
		60-90	3.25	5.00	1.97	0.68	0.30	0.05
Aghormi	8	0-45	3.25	7.23	2.24	0.57	0.31	0.07
		45-85	3.00	6.00	2.00	0.66	0.33	0.13
		85-150	3.84	9.13	2.70	0.43	0.17	0.10
Qureishet	12	0-45	3.41	9.38	2.50	0.49	0.20	0.04
		45-60	3.67	7.85	2.50	1.13	0.56	0.08
		60-100	3.25	6.50	2.17	0.48	0.24	0.05
Abu-shrouf	14	0-45	7.00	4.67	2.80	0.49	0.24	0.05
		45-95	3.42	8.12	2.41	0.73	0.41	0.21
		95-150	3.04	7.57	2.17	0.76	0.39	0.05
El-Zeitun	17	0-55	3.11	6.55	2.11	0.68	0.32	0.10
		55-85	3.93	7.86	2.62	0.84	0.45	0.05
		85-150	4.34	8.13	2.83	0.55	0.32	0.01
Timeira	19	0-10	6.01	6.01	3.00	0.64	0.36	0.06
		10-40	3.93	5.50	2.29	0.55	0.38	0.08

*** Notes:**

Z= Zircon **Wr1 = Pyroxenes + Amphiboles/ Zircon + Tourmaline.**
R= Rutile **Wr2 = Amphiboles/ Zircon + Tourmaline.**
T= Tourmaline **Wr3 =Biotite / Zircon + Tourmaline**

4.12. Mineralogy of the clay fraction (<0.002 mm Ø):

X-ray diffraction analysis was undertaken for a selected 24 soil samples representing the soils containing appreciable amounts of clay. **Table 19; and Figs 7 to 15.** Samples were subjected to mineralogical interpretation on a semi-quantitative level. The X-ray pattern obtained from the diffractometer scans of oriented samples was and used for identification of clay and accessory minerals following the criteria established by **Whittig and Jackson (1955), Brown (1961) and Black et al (1965)**.

Concerning the presence of the four clay minerals of kaolinite, smectite, illite, and attapulgite in the clay fractions, results show that the clay fraction of the soils of El-Maraqui, Khamisa, Siwa, Aghormi, El-Zeitun, and Timera (profiles 2, 5, 6,8,17, and 19 respectively) is dominated by kaolinite as its presence range between moderate (15-25%) amounts to dominant (25-40 %). In the other regions, kaolinite are in traces (<5 %) to moderate (15-25%) amounts. Smectites (montmorillonite) are mainly present in few (5-15 %) to moderate (15-25 %) in El-Maraqui, kamisa, and Aghormi regions. In the other regions smectites are in traces. Illites are detected in small amounts in all regions, and range from traces to moderate contents like illites. Attapulgites are generally present in traces to few content. Palygorskite is present in most samples in moderate amounts of increasing with depth in of profiles 2 and 8.In respect to the accessory minerals, quartz and feldspars are detected in variable amounts. Quartz ranges between few and moderate amounts, being rather high in (85-150 cm) layer of profile 5. Feldspars range from traces to few amounts and their content are rather high in the surface layer of profile 8. Calcite and dolomite minerals are also detected in the clay fraction as trace to moderate amounts.

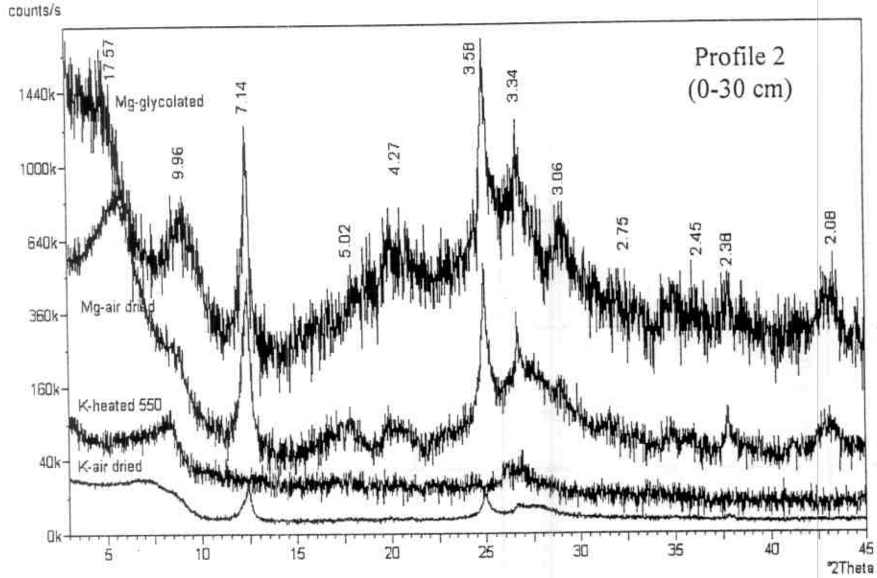
With regard to soils of Qureishet and Abu-Shrouf which are represented by profiles 12 and 14, the X-ray diffractograms of the separated clays of these soils indicate that their mineralogical components are quite different from those of the soils of Siwa oasis. The X-ray patterns **(Figs 12 to 13)** reveal that, the clay fraction of these soils (profiles 12 and 14) are predominated by palygroskite, which few amounts in the surface (0-45 cm) layer of profile 14 and increases with depth to moderate amount. Kaolinite is the second predominant clay mineral decreasing with depth. Montmorillonite and illite minerals occur in less content followed by attapulgite. The identified accessory minerals are mainly dominated by quartz and feldspars, with calcite and dolomite being in moderate amounts.

With regard to soils of El-Zeitun and Timeira which are represented by profiles 17 and 19 results in **(Table 19 and Figs 14 to 15)**, the clay fraction of these soils is dominated by kaolinite followed by attapulgite then illite. Smectite and palygroskite minerals are also detected in few amounts. The accessory minerals are mainly dominated by quartz and feldspars while calcite and dolomite are found in few amounts.

Table 19: Frequency distribution of the clay minerals of the clay fraction (< 0.002 mm Ø) separated from the soils of Siwa Oasis

Region	Profile No.	Depth, cm	Clay minerals					Accessory Minerals			
			Smectites	Kaolinite	Illite	Attapulgite	Palygorskite	Feldspars	Calcite	Dolomite	Quartz
El-Maraqui	2	0-30	++	+++++	+	+	+	+	+++	+	+
		30-60	++	++++	+	+	++	+	++	++	+
		60-90	+++	++++	+	++	+	+	+	+	+
		90-150	+++	++++	+	+	+++	++	+	++	++
Khamisa	5	0-40	+	+++	+	+	+	+++	++	+	++
		40-80	++	++++	++	+	+	++	+	+	+
		80-150	++	++++	+	+	+	+	+	++	+
Siwa	6	0-30	+	+++	++	+	+	+	++	+	+
		30-60	+	++++	+	+	++	+++	++	+	+
		60-90	+	++++	++	+	+	+	+	++	+
Aghormi	8	0-45	+++	++++	+	+	+	+++	+	++	+
		45-85	+	++++	++	+	++	+	+	++	++
		85-150	++	++	++	+	+++	+	+	++	++
Qureishet	12	0-45	+	+++	+	+	+	+++++	+++	++	+++
		45-60	+	+	+	+	++	+++++	++++	+++	++++
		60-100	+	+	+	+	+++	+++++	+	++++	++++
Abu-Shrouf	14	0-45	+	++	++	++	+	+++	++	++	+++
		45-95	+	++	+	++	+++	+	++++	+++	++++
		95-150	+	+	+	++	+	+	++	+++	+++
El-Zeitun	17	0-55	+	+++++	+	+++	+	+	+	+	+
		55-85	+	++++	+++	+	+	+	+++	+++	+
		85-150	+	+++	+	+++	+	+	+	+	+
Timeira	19	0-10	+	++	+	+	+	+++++	+++	++	++++
		10-40	+	+++	+	+	+	++++	+++	++	++

Trace +: < 5% Few ++: 5-15 %
Moderate +++: 15-25 % Common ++++: 25-40 % Dominant +++++: >40 %



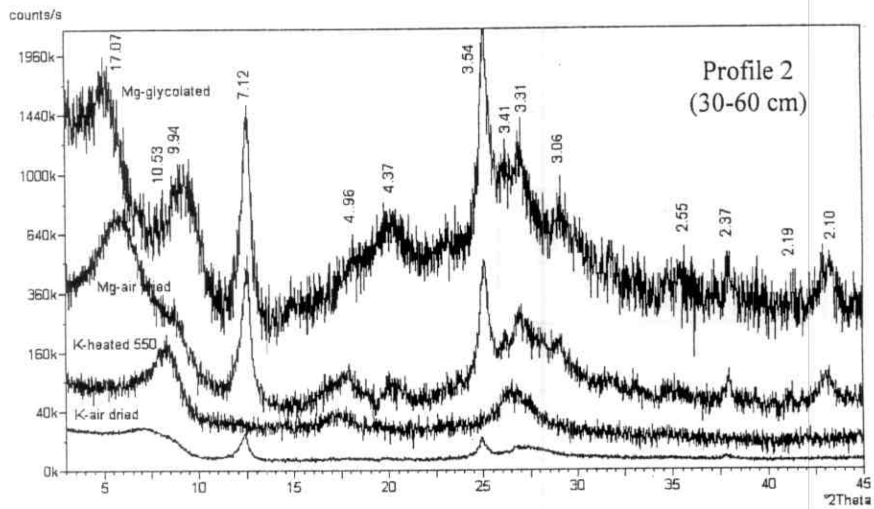
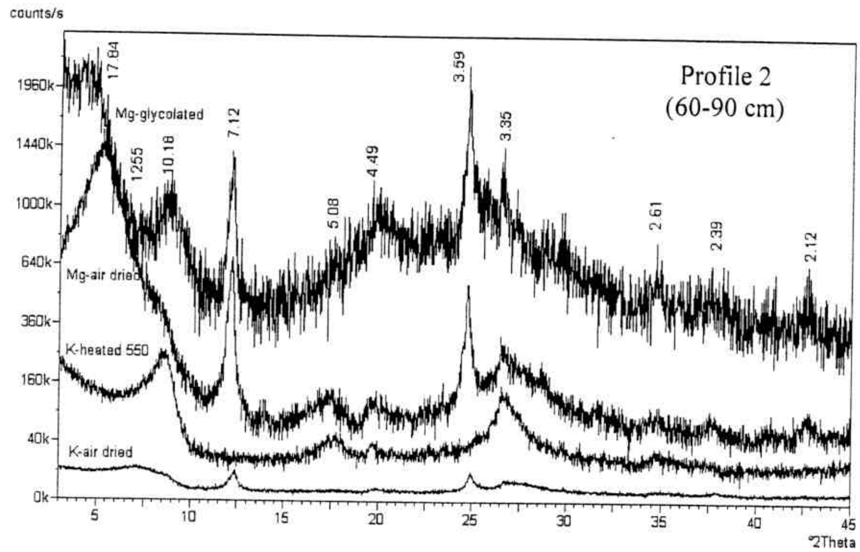


Fig.(7): X-ray diffractograme of the clay fraction separated from profile 2 of EL- Maraud region



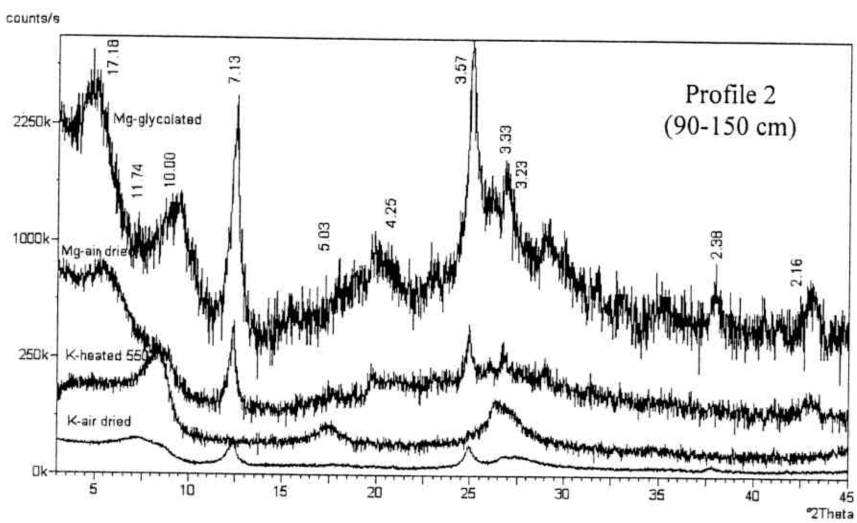


Fig. (8): X-ray diffractograme of the clay fraction separated from profile 2 Of EL- Maraqui region

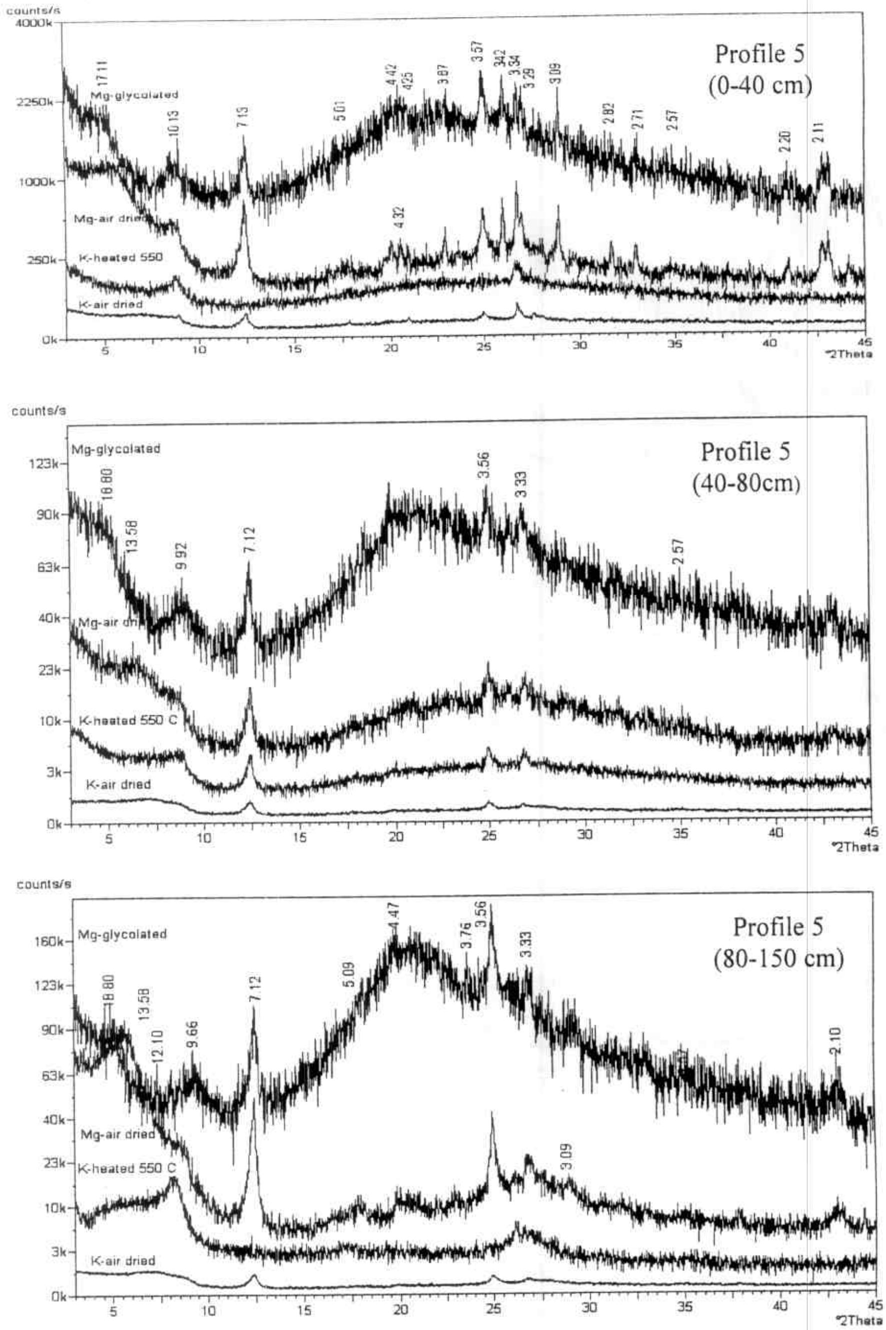


Fig. (9): X-ray diffractograme of the clay fraction separated from profile 5 of Khamisa region.

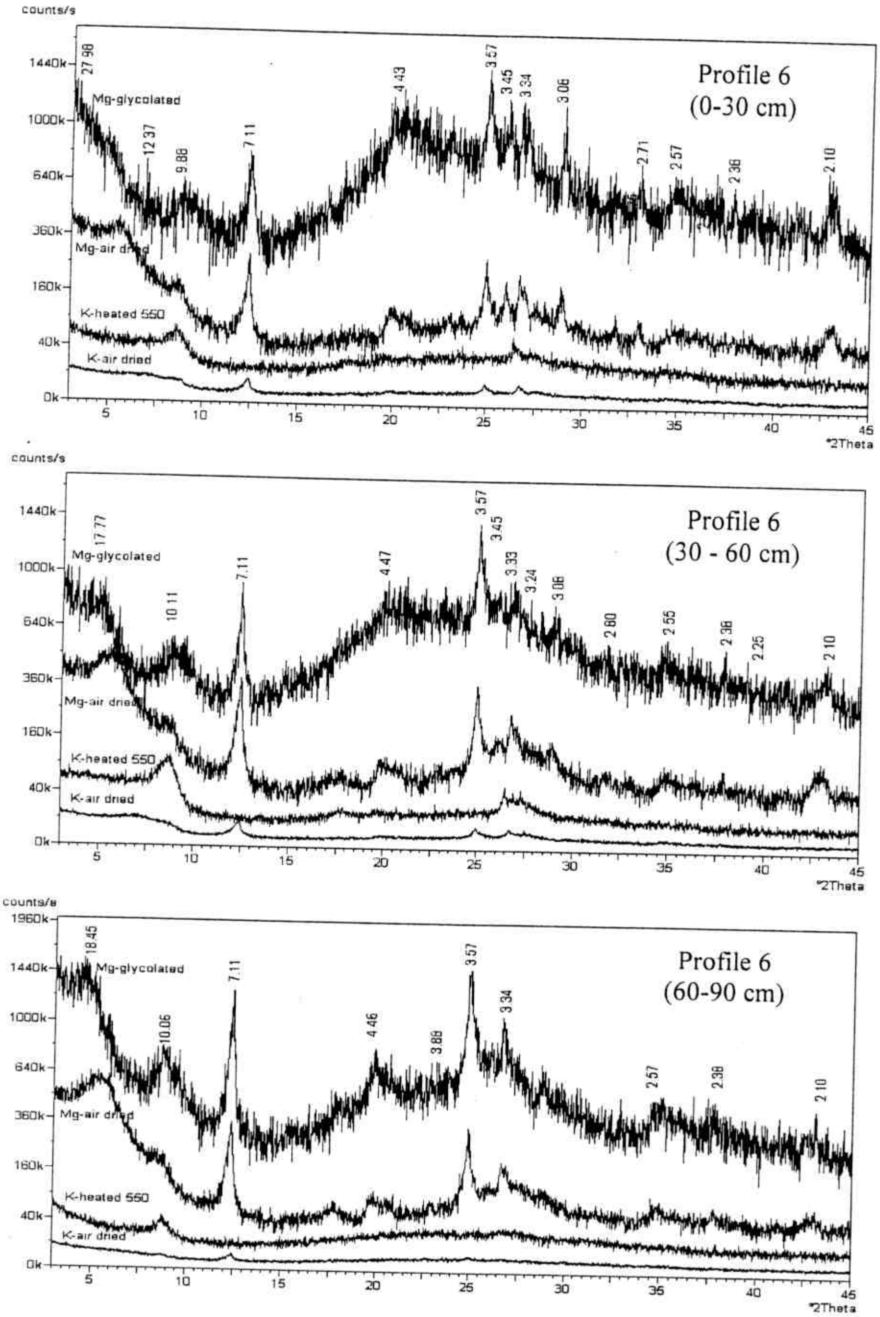


Fig. (10): X-ray diffractograme of the clay fraction separated from profile 6 Of Siwa Oasis region

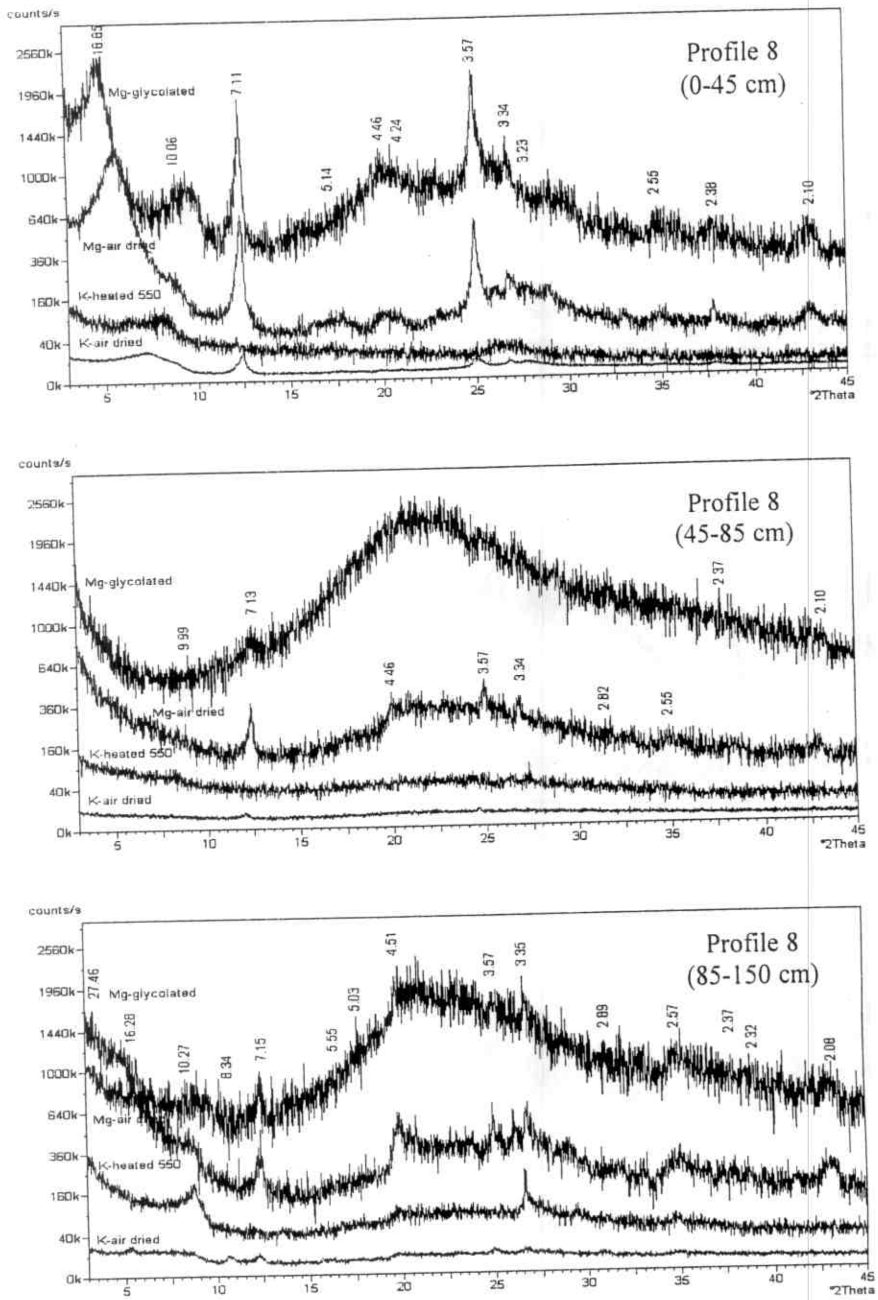


Fig. (11): X-ray diffractograme of the clay fraction separated from profile 8 Aghormi region

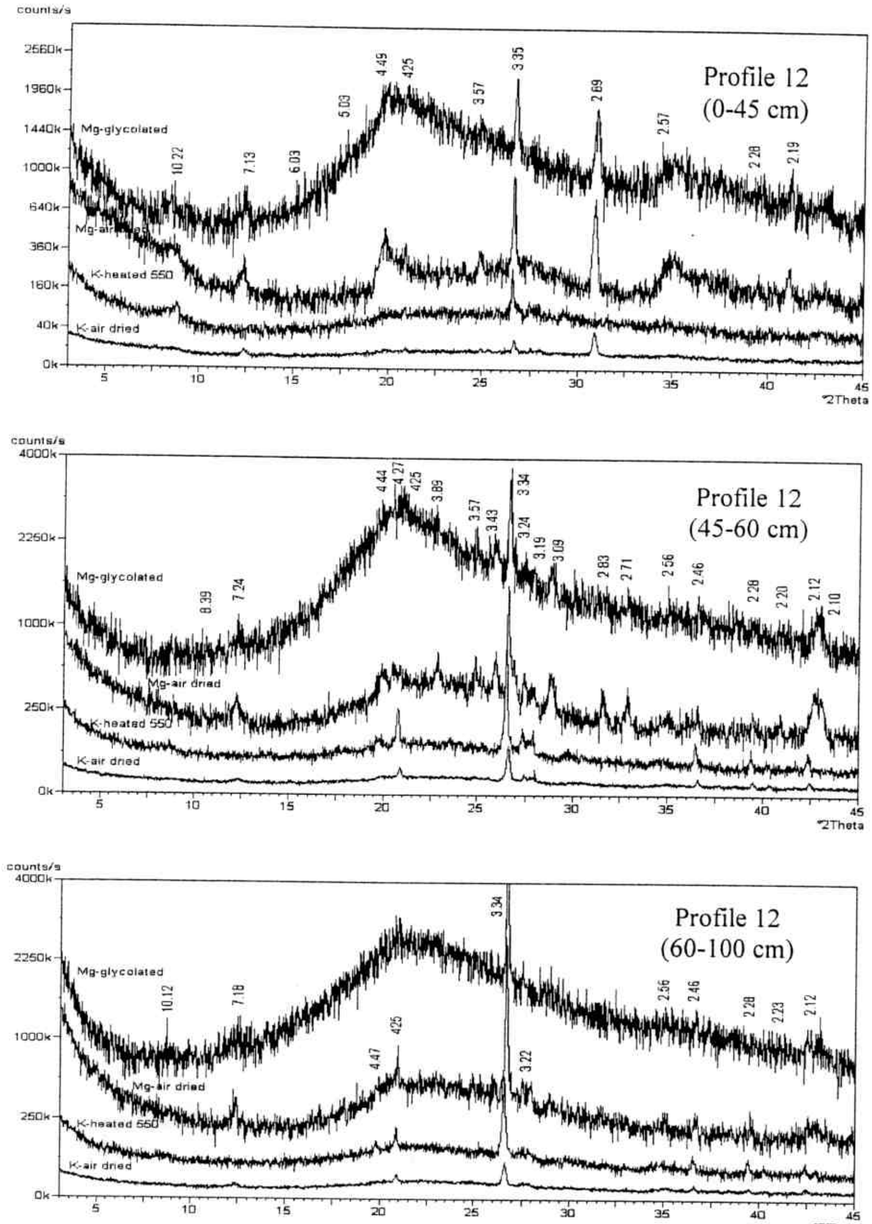


Fig. (12): X-ray diffractograme of the clay fraction separated from Profile 12 of Qureishet region

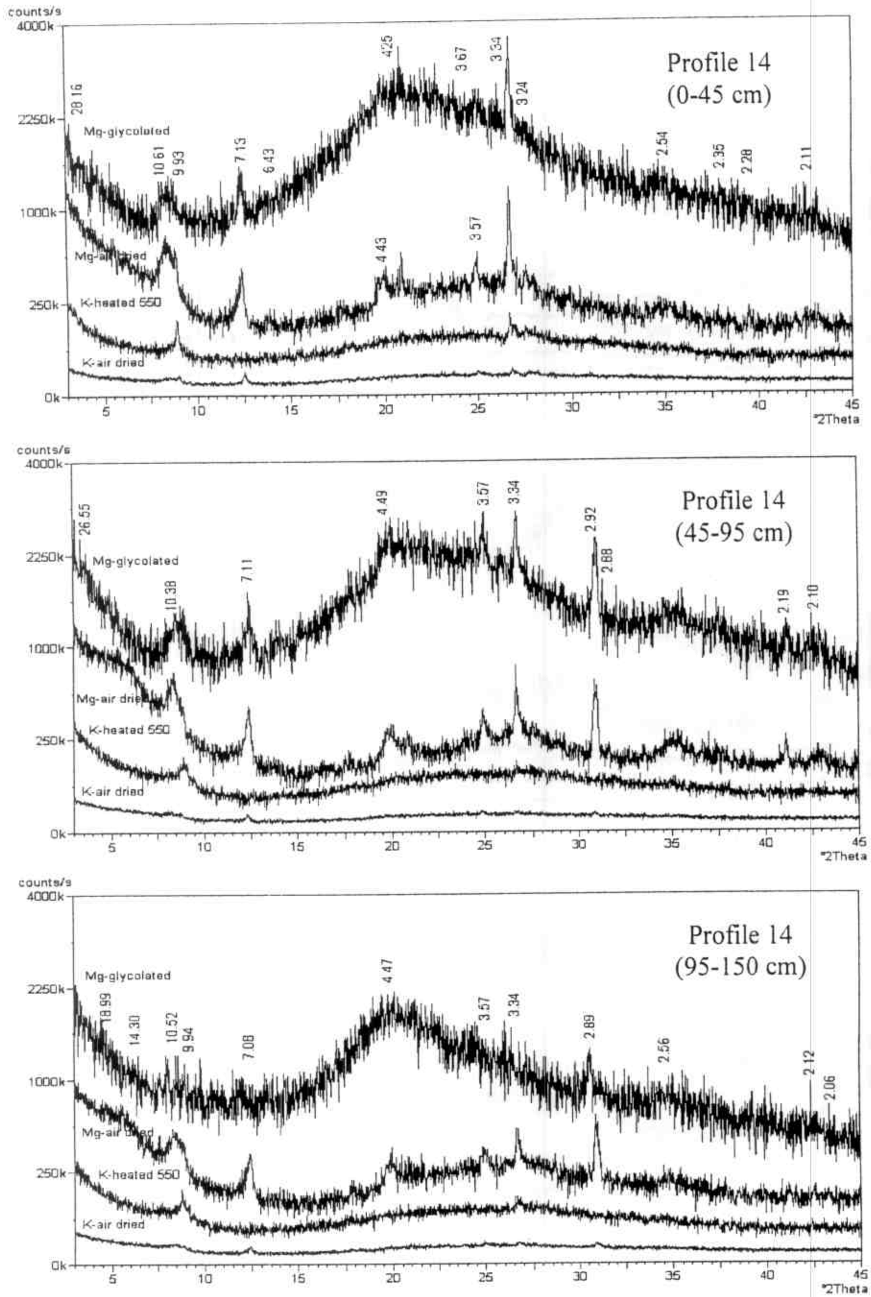


Fig.(13) X-ray diffractograme of the clay fraction separated from profile 14 of Abu-Shrouf region.

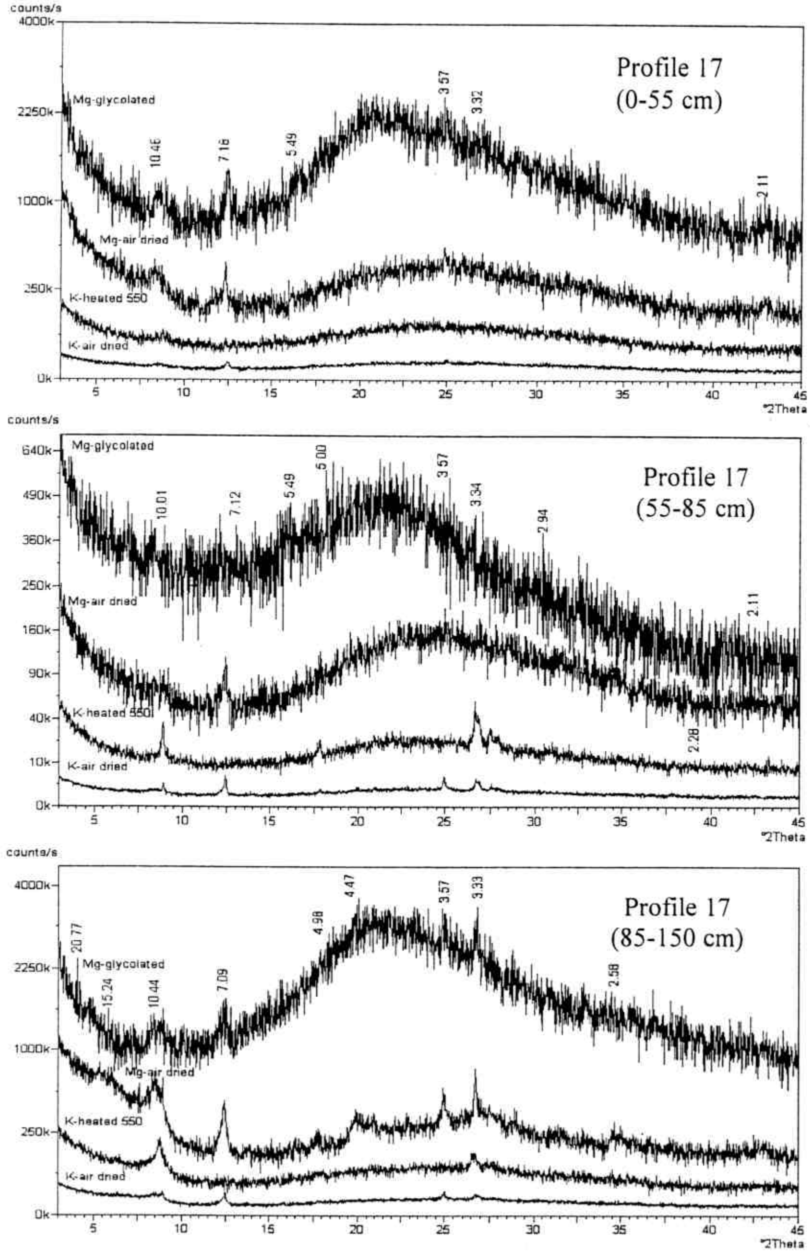


Fig. (14): X-ray diffractograme of the clay fraction separated from profile 17 of EL-Zeitun region.

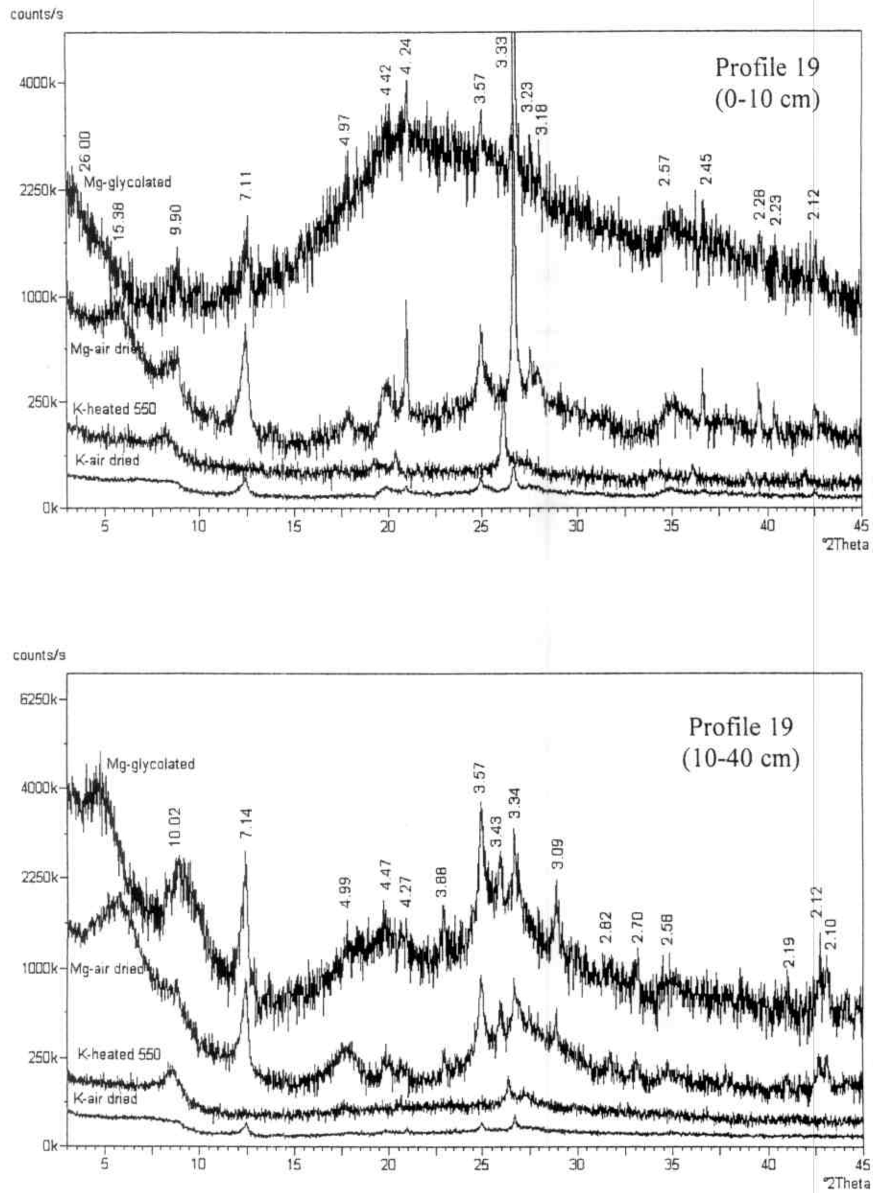


Fig. (15): X-ray diffractograme of the clay fraction separated from profile 19 of Timeira region.

4.12.1. Conclusive remarks on mineralogy of the clay fraction:

From the aforementioned results, it can be concluded that the soils of Siwa oasis are dominated by kaolinite while smectite is the second predominant clay mineral followed by illite, palygorskite and attapulgite. These results indicate that such minerals may be of geological origin, inherited from a parent material which was mainly a limestone in Siwa oasis **(Labib, 1970).** Clays of these soils contain relatively small amounts of magnesium bearing minerals such as palygroskite. This indicates the alkaline nature of the sedimentary environment, where moderate amounts of magnesium were available. **Dixon and Weeds (1977)**, the presences of palygroskite reveal that, this clay mineral is mostly probably inherited from a formation rich in Mg ions and $CaCO_3$.

4.13. Mineralogy of the silt fraction (0.02-0.002 mm Ø):

X-ray diffraction analysis was undertaken for a selected 24 soil samples representing the soils containing appreciable amounts of silt **(Table 20; and Figs 16 to 24).** Samples were subjected to mineralogical interpretation on a semi-quantitative level.

With regard to soils of El-Maraqui, Khamisa, Siwa and Aghormi, which are represented by profiles 2, 5, 6 and 8, kaolinite is the predominant as it constitutes between few to common in the samples. Hydrous mica (illites) are the second predominant and representing relatively minor amounts (from traces to moderately amounts) decreasing with depth in the soils of profile 2. Smectite is also detected in fairly small

Table 20: Frequency distribution of the silt fraction (0.02-0.002 mm Ø) separated from the soils of Siwa oasis.

Region	Profile No.	Depth, cm	Minerals									
			Smectite	Kaolinite	Illite	Meta-Halloysite	Chl./Ver.or Chl./Sme.	Quartz	Calcite	K-feldspars	olivine	Amphiboles
El-Maraqui	2	0-30	++	++	++	+	+	+++	++	+	+	+
		30-60	+++	+	++	+	+	+++	++	+	+	+
		60-90	+	+++	++	++	+	+	+	+	+	+++
		90-150	+	+++	+	+	+	+++	+	+	+	+
Khamisa	5	0-40	+	+	+	+	+	+++++	+	+	+	+
		40-80	+	+++	+++	+	+	++++	+	+	+	+
		80-150	+	+	+	+	+++	+++	+++	+	+	+
Siwa	6	0-30	+	+	+	+	+	++++	+	+	+	+
		30-60	+	+	+	+	+++	+	+	+	+	++
		60-90	+	+	+	+	+	++++	+	+++	+	+
Aghormi	8	0-45	+	+++	+	+	++	++	+	+	+	++
		45-85	+++	+	+	+	+	++	+	+	+	+
		85-150	++	+	+++	+	++	+	+	+	+	+++
Qureishet	12	0-45	+	+	+	+	+++	++++	+	+	+	+
		45-60	+	+	+	+	+	+++++	+	+	+	+
		60-100	++	+	++	+	+	++++	+	+	+	+
Abu-Shrouf	14	0-45	+	+	+	+	+++	+++	++	+	+	++
		45-95	++	++	+	++	+	+++	+	+	+	+
		95-150	+	+++	++	+	+	+++	+++	+	+	+
El-Zeitun	17	0-55	++	+	+	+	++	+	+	+	+	++
		55-85	++	+	++	+	++++	+	+	+	+	+
		85-150	+	++	+	+	+++	++	+	+	+	++
Tempera		0-10	+++	+	+	+	+++	+	+	+	+	++
	19	10-40	+++	++	+	+	+++	+	+	+	+	+++

Trace. + : < 5%s Chl.: Chlorite Ver: VermiculiteSme.: Smectite
Few ++: 5-15 % Moderate +++: 15-25 %
Common ++++: 25-40 % Dominant +++++ : >40 %

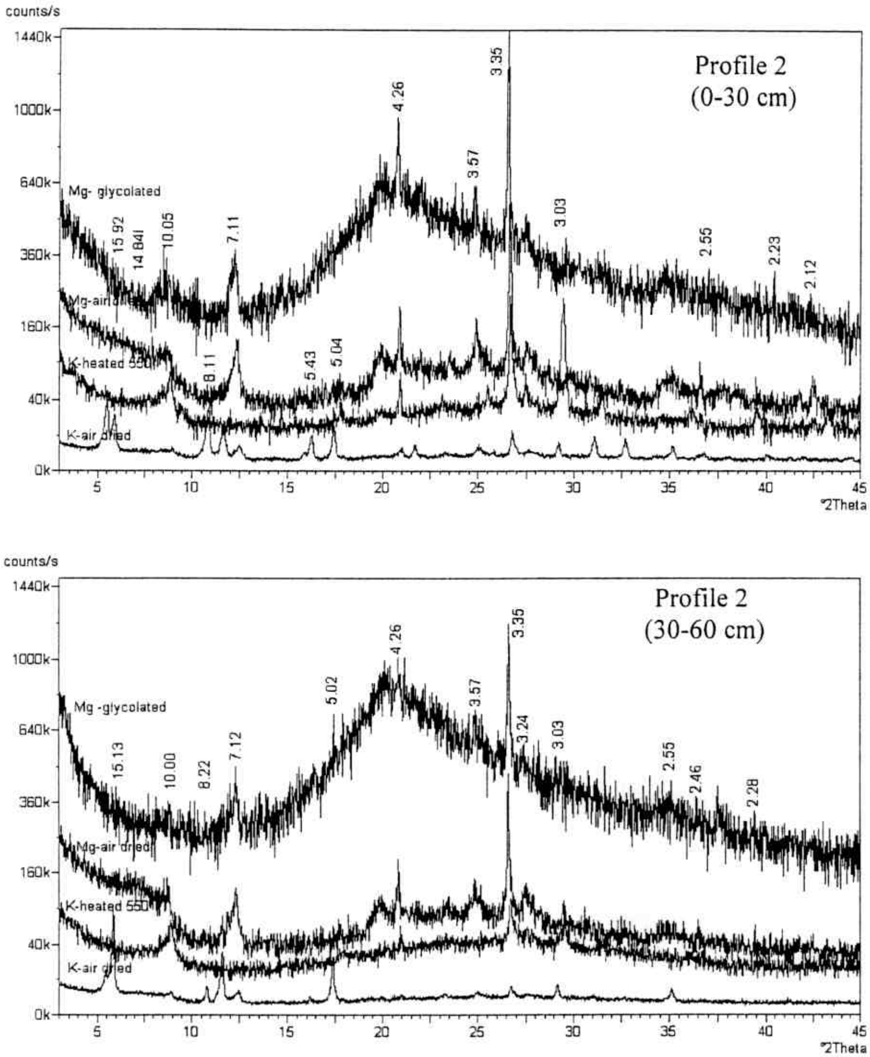


Fig. (16): X-ray diffractograme of the silt fraction separated from profile 2 of El-Maraqui region.

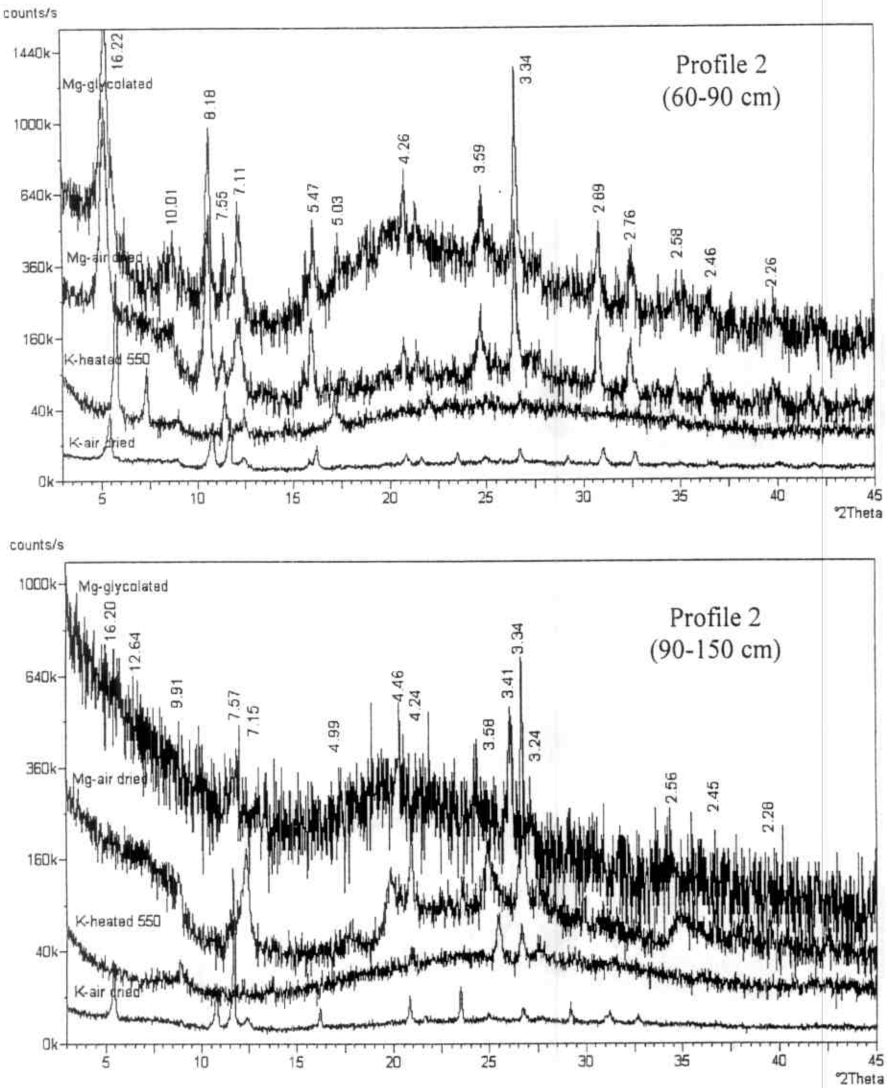


Fig. (17): X-ray diffractograme of the silt fraction separated from profile 2 of El- Maraqui region.

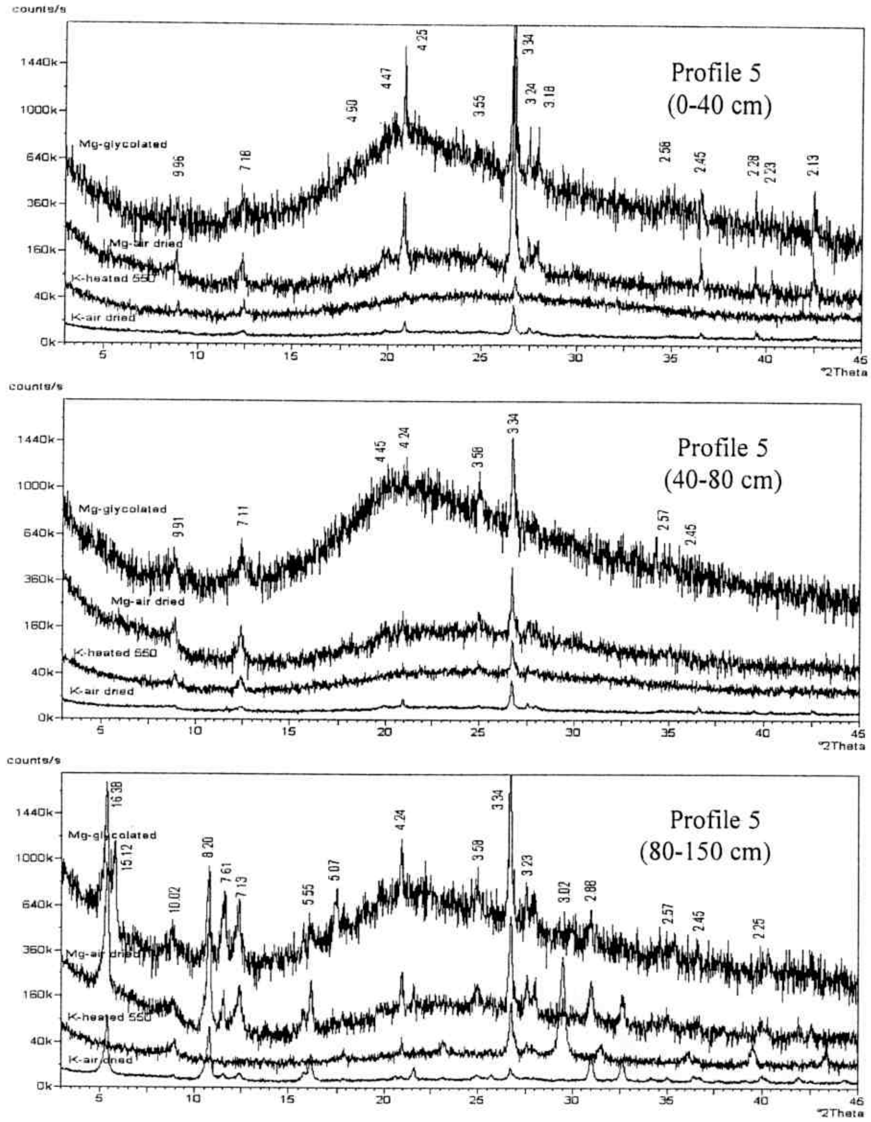


Fig. (18): X-ray diffractograme of the silt fraction separated from profile 5 of Khamisa region.

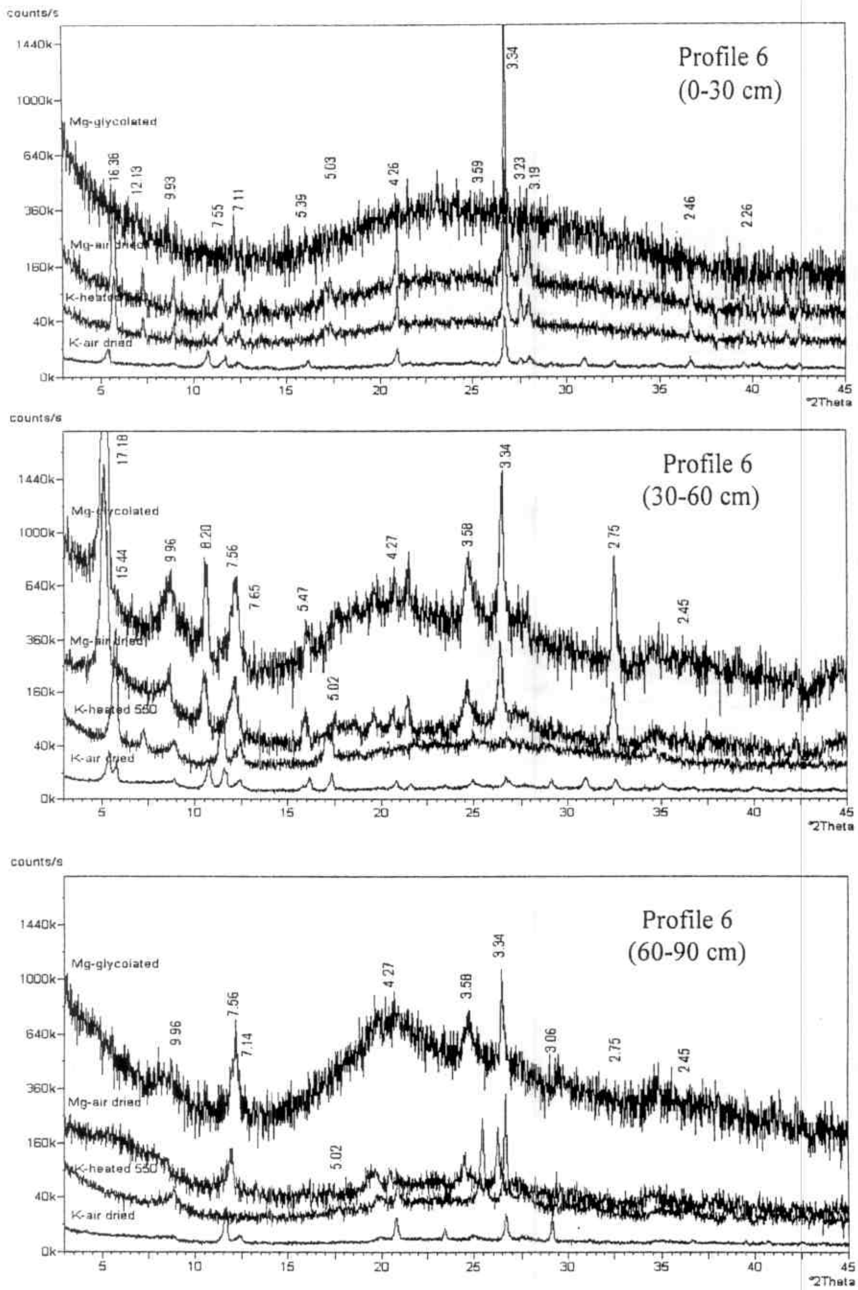


Fig. (19): X-ray diffractograme of the silt fraction separated from profile 6 of Siwa region.

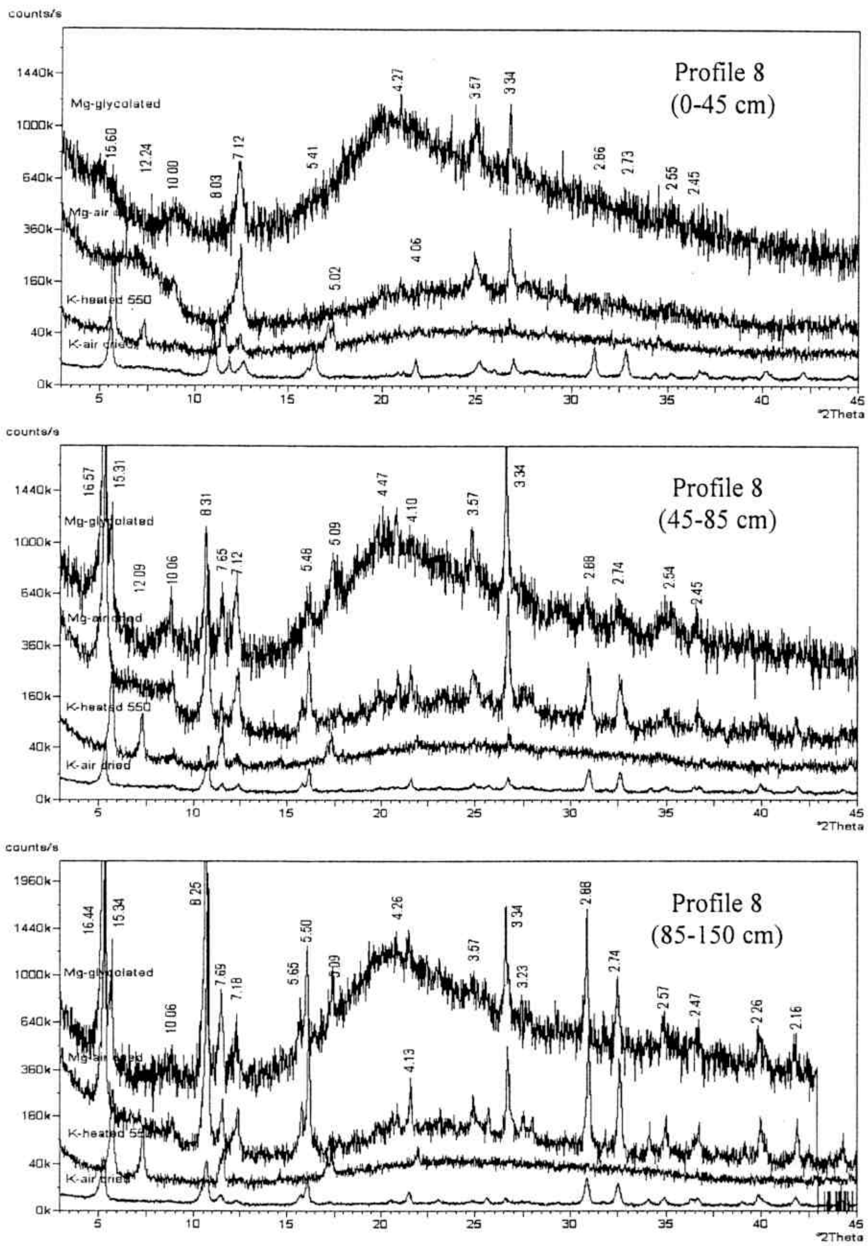


Fig. (20): X-ray diffractograme of the silt fraction separated from profile 8 of Aghormi region.

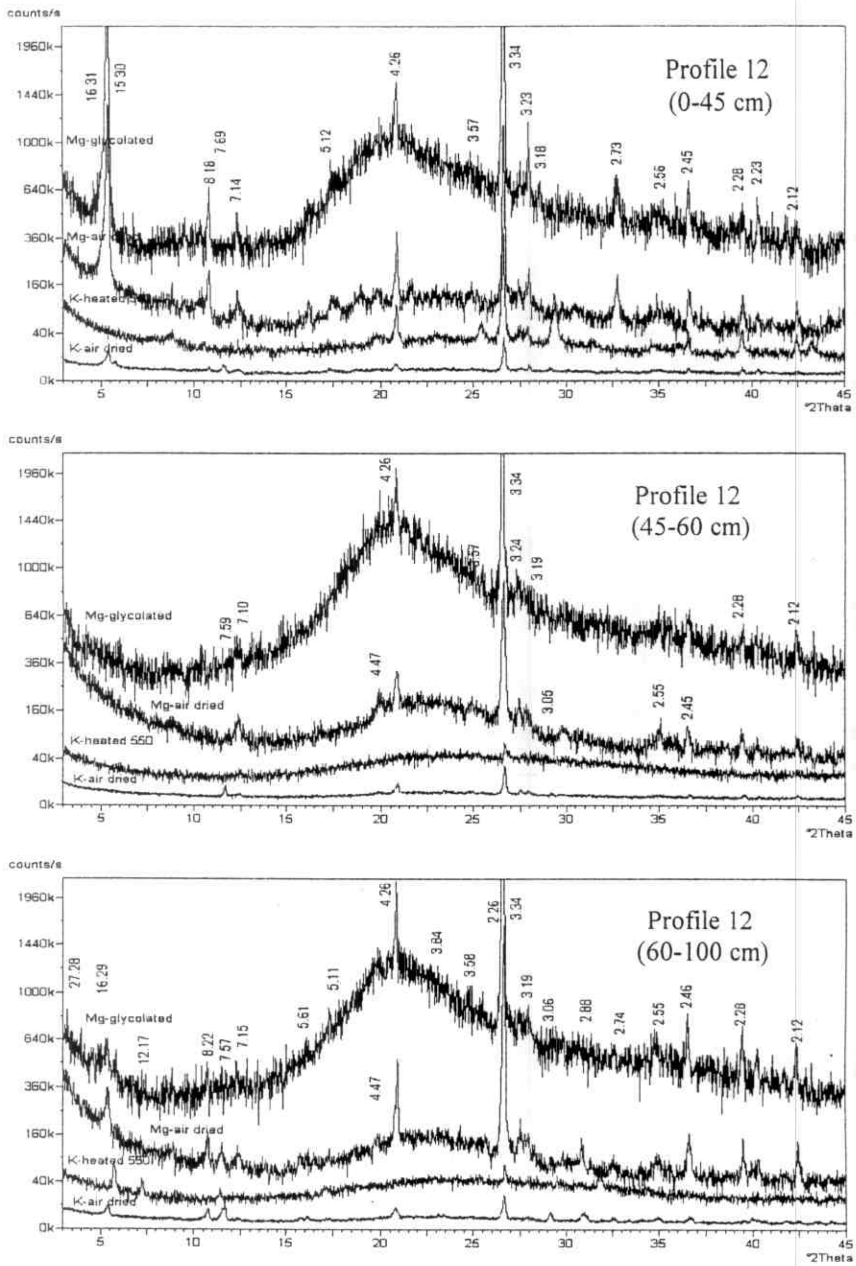


Fig. (21): X-ray diffractograme of the silt fraction separated from profile 12 of Qureisht region.

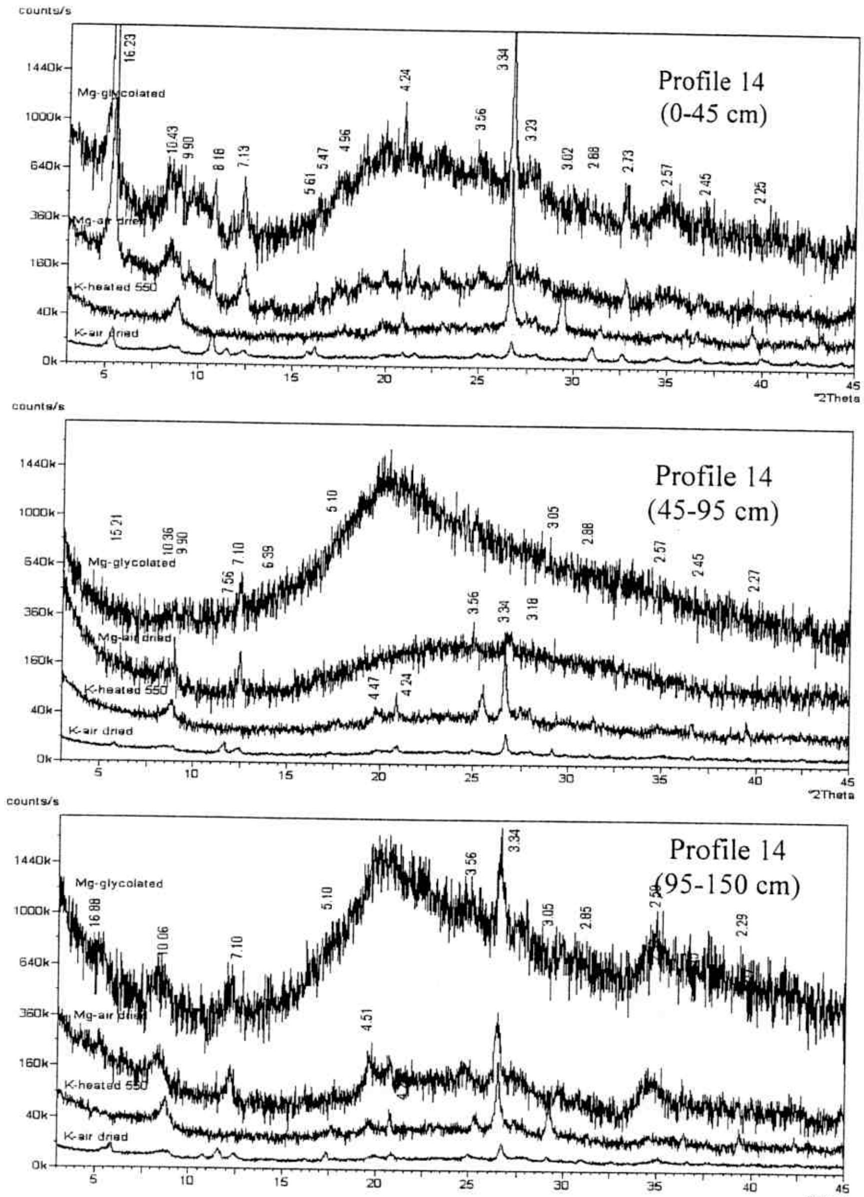


Fig. (22): X-ray diffractograme of the silt fraction separated from profile 14 of Abu-Shrouf region.

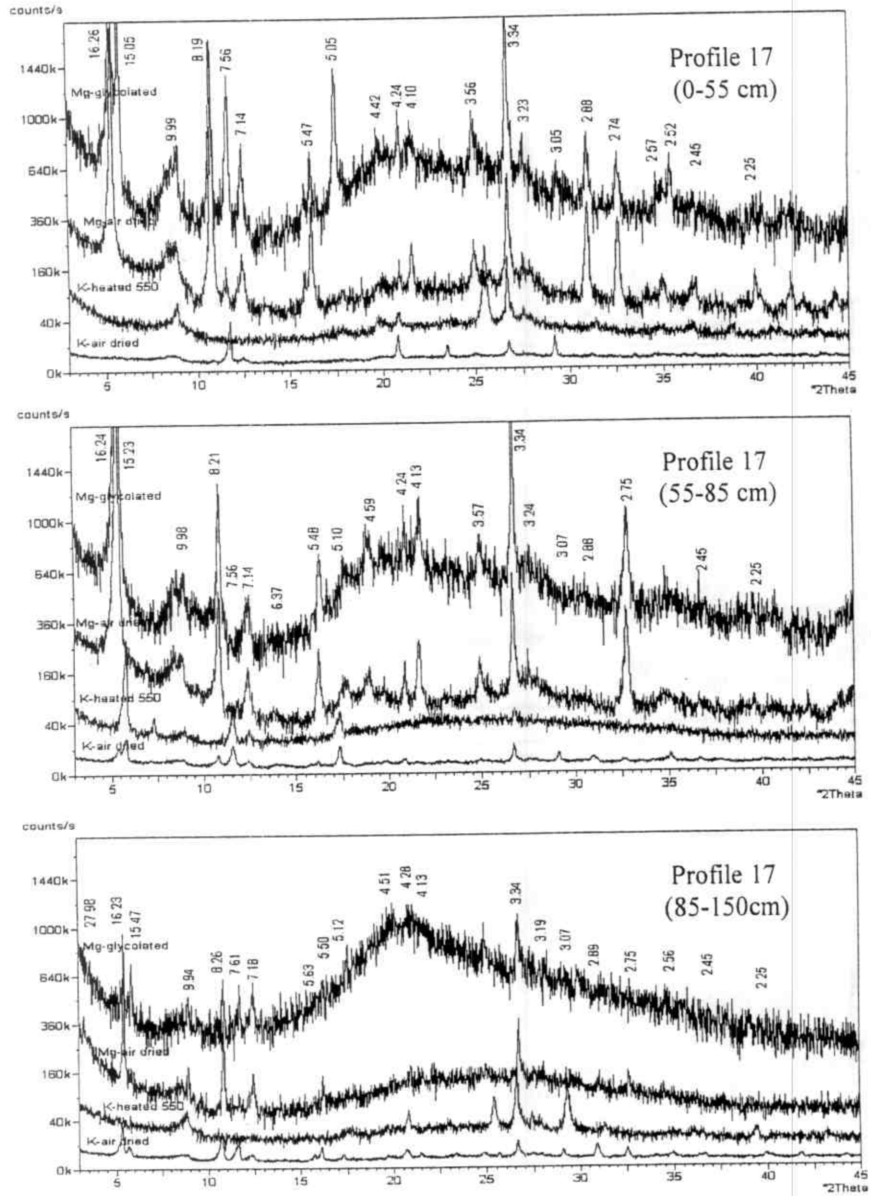


Fig. (23): X-ray diffractograme of the silt fraction separated from profile 17 of EL-Zeitun region.

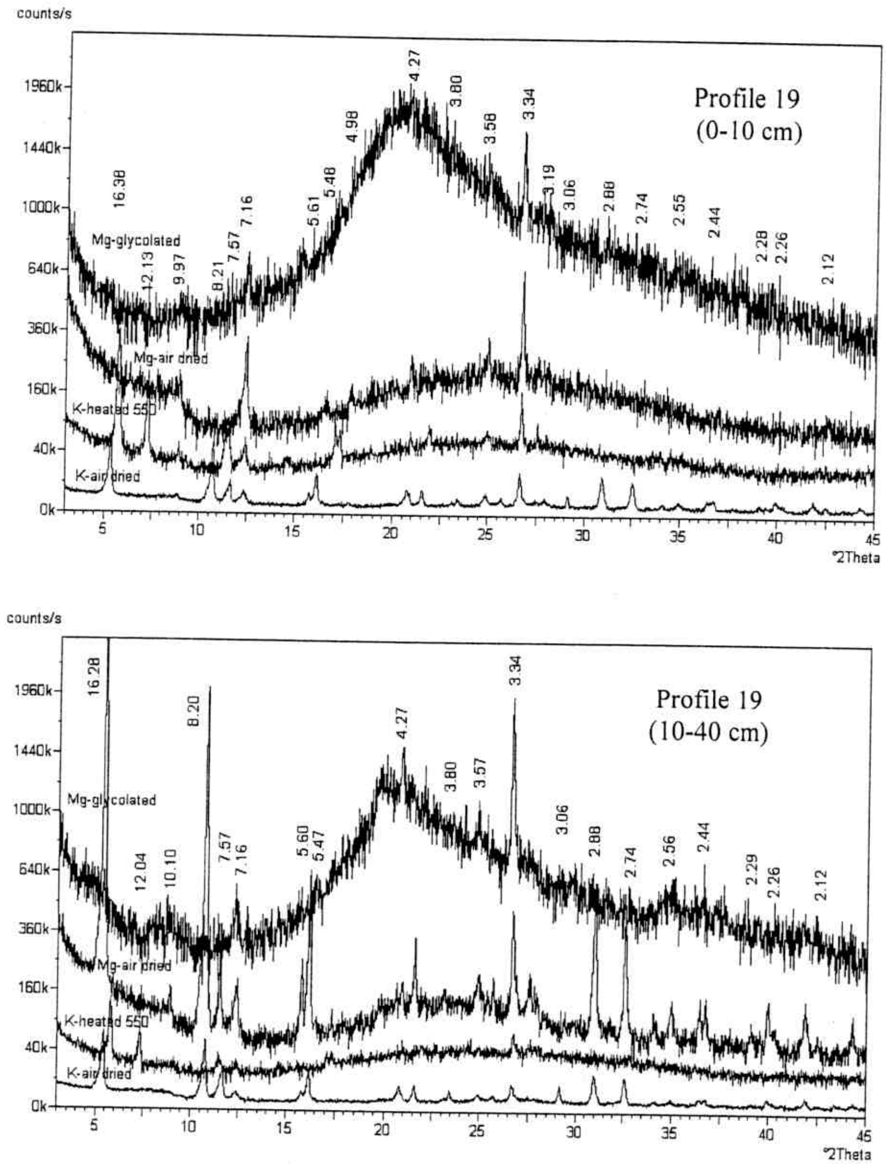


Fig. (24): X-ray diffractograme of the silt fraction separated from profile 25 of Timeira region.

amounts ranging from traces to moderate amounts and increasing with depth in the soils of profile 8. Chlorite/ vermiculite or Chlorite/smectite are present in most samples in moderate amounts; and from traces to moderate amounts, increasing with depth in profiles 2 and 8. Meta-Halloysite is present in all the samples in a less pronounced a mounts. In respect to the accessory minerals, quartz and amphiboles are detected in the silt fraction of all the studied samples. Quartz ranges between few to dominant amounts being higher in surface (0-40 cm) layer of profile 5. Amphiboles content ranges from traces to common amounts and its content is higher in the deepest (85-150 cm.) layer of profile 8. Calcite, feldspars and olivine minerals are also detected in the silt fraction in trace to moderate amounts.

With regard to soils of Qureishet and Abu-Shrouf which are represented by profiles 12 and 14, the X-ray diffractograms of the separated silt of these soils indicate that their mineralogical components are quite different from those of the other soils of Siwa oasis. The X-ray patterns (**Figs 21 to 22)** reveal that, the silt fraction of these soils (profiles 12 and 14) are predominated by chlorite/vermiculite or chlorite/ smectite which constitutes common amounts of the silt content of the surface (0-45 cm.) layer of profile 12 decreasing with depth. Kaolinite mineral is the second predominant mineral increasing with depth. Smectite and illite are also recorded is less amounts than kaolinite. Meta-halloysite mineral is detected in few amounts. The identified accessory minerals are mainly dominated by quartz and calcite, while the K-Feldspars, olivine and amphiboles are detected between traces to few amounts.

With regard to soils of El-Zeitun and Timeira represented by profiles 17 and 19 and shown in **Table 20 and Figs 23 to 24**, data reveal that the silt fraction of these soils is dominated by chlorite/vermiculite or chlorite/smectite followed by smectite then kaolinite. Illite and meta-halloysite minerals are also detected in few to moderated amounts. The accessory minerals are mainly dominated by amphiboles and quartz while calcite, K- feldspars and olivine are found in traces.

4.13.1. Conclusive remarks on mineralogy of the silt fraction:

From the aforementioned results, it can be concluded that the soils of Siwa oasis are dominated by Chlorite/Vermiculite or Chlorite/ Smectite while Kaolinite is the second predominant silt minerals followed by Smectite, illite, and Meta-halloysite. These minerals may be of geological origin, and inherited from parent limestone rocks **(Labib, 1970))**.

4.14. Mineralogy of the fine sand fraction (0.02-0.002 mm Ø):

X-ray diffraction analysis was undertaken for a selected 24 soil samples representing the soils containing appreciable amounts of fine sand**. Table 21, and Figs 25 to 28.**

The X-ray patterns reveal that the fine sand fraction of Siwa oasis which are represented by profiles 2,5,6,8,12,14,17and 19 are dominated by quartz as it constitutes between common to dominate amounts of the fine sand of these samples. Calcite mineral is the second in abundance and is present in relatively less amounts (few to moderate) and decreases with depth in the soils of profiles 12 of Qureishet region. Dolomite, olivine, gypsum, hematite, goethite and

K-feldspars are also detected in the fine sand fraction in trace to few amounts.

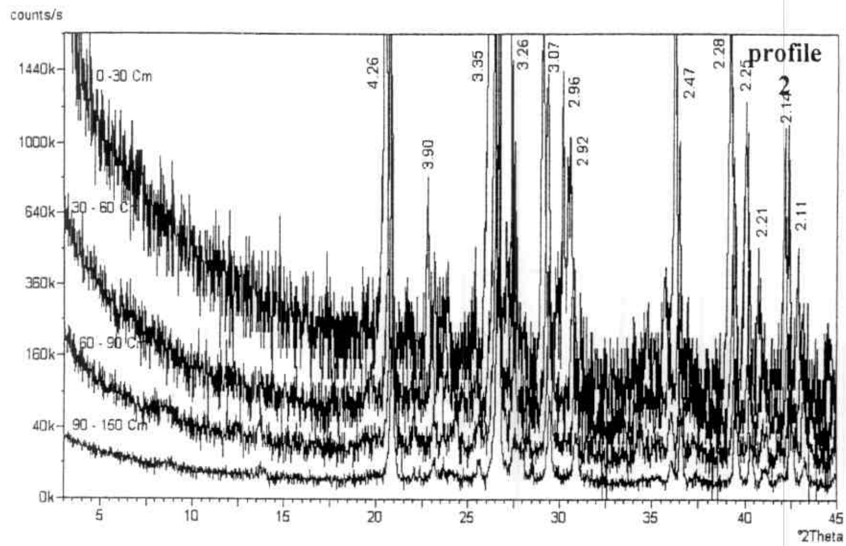
4.15 Land capability classification:

The land capability classification is one of a number of interpretive groupings made primarily for agricultural purpose. The prime aim of the system is to asses the degree of limitation to land use or potentials imposed by land characteristics on the basis of permanent properties. In this respect, many systems have been suggested to evaluate the agricultural limitations affecting land capability under the prevailing conditions. All systems aim at gaining informative knowledge and greater enlightement in understanding the properties of the soils and defining limitations affecting their agricultural potentialities. **Table 22** shows the grades and the values that can be used as a guide in rating the soils, (rating according to **Storie 1964 and Sys 1991):**

Table 21: Frequency distribution of minerals in the fine sand fraction (0.2-0.02 mm Ø) of the Fraction separated from the soils of Siwa oasis.

Region	Profile No.	Depth, cm	Minerals							
			Quartz	Dolomite	Olivine	Calcite	Gypsum	Hematite	Goethite	K-Feldspars
El-Maraqui	2	0-30	+++++	+	+	+	+	+	+	+
		30-60	++++	+	+	++	+	+	+	+
		60-90	+++++	+	+	+	+	+	+	+
		90-150	+++++	+	+	+	+	+	+	+
Khamisa	5	0-40	+++++	+	+	++	+	+	+	+
		40-80	+++++	+	+	++	+	+	+	+
		80-150	++++	+	+	+	+	+	+	+
Siwa	6	0-30	+++++	+	+	+	+	+	+	+
		30-60	+++++	+	+	+	+	+	+	+
		60-90	++++	++	+	++	+	+	+	+
Aghormi	8	0-45	+++++	+	+	+	+	+	+	+
		45-85	++++	+	+	++	+	+	+	+
		85-150	++++	++	+	++	+	+	+	+
Qureishet	12	0-45	++++	+	+	+++	+	+	+	+
		45-60	++++	+	+	++	+	+	+	+
		60-100	++++	+	+	+	+	+	+	+
Abu-Shrouf	14	0-45	+++++	+	+	+	+	+	+	+
		45-95	++++	+	+	++	+	+	+	+
		95-150	++++	+	+	++	+	+	+	+
El-Zeitun	17	0-55	++++	+	+	++	+	+	+	+
		55-85	++++	+	+	++	+	+	+	+
		85-150	+++++	+	+	+	+	+	+	+
Timeira	19	0-10	+++++	+	+	+	+	+	+	+
		10-40	+++++	+	+	+	+	+	+	+

Trace.	+ :	< 5%s	Few	++:	5-15 %
Moderate	+++:	15-25 %	Common	++++:	2 5-40 %
Dominant	+++++ :	>40 %			



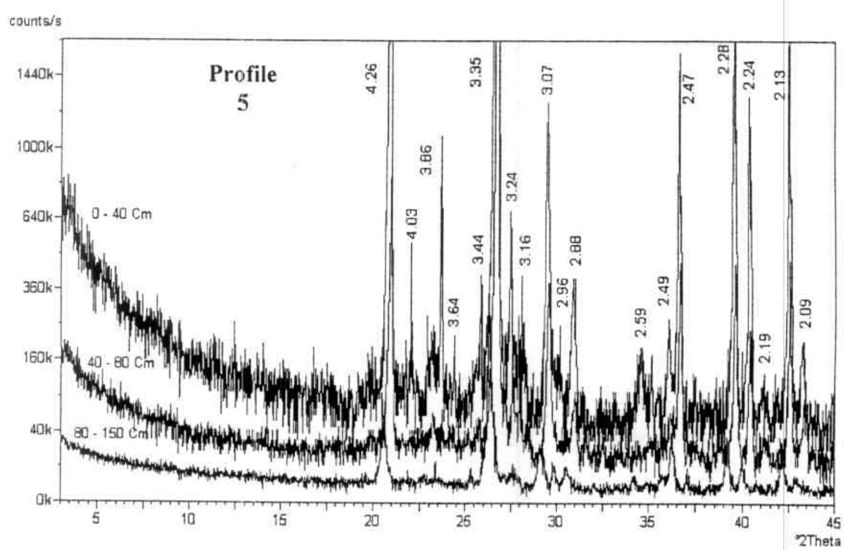


Fig. (25): X-ray diffractograme of the fine sand fraction separated from profiles 2 and 5 of El-Maraqui and Khamisa regions.

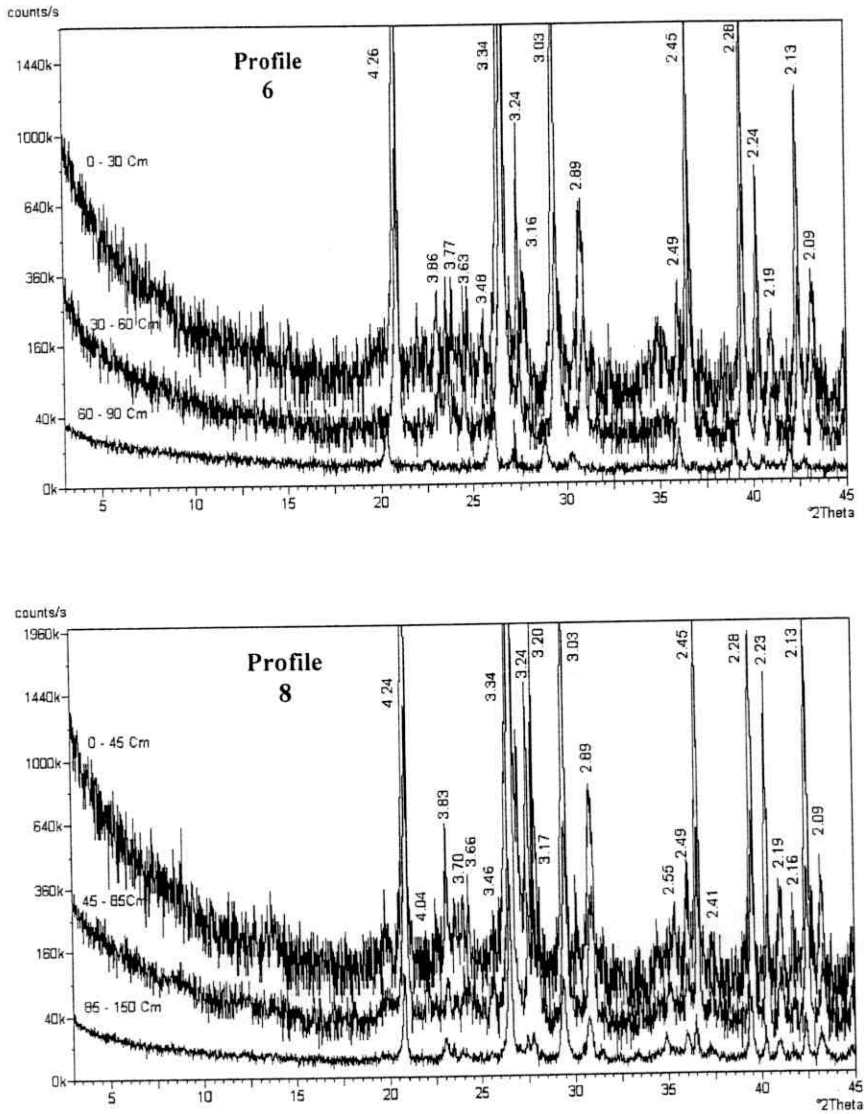
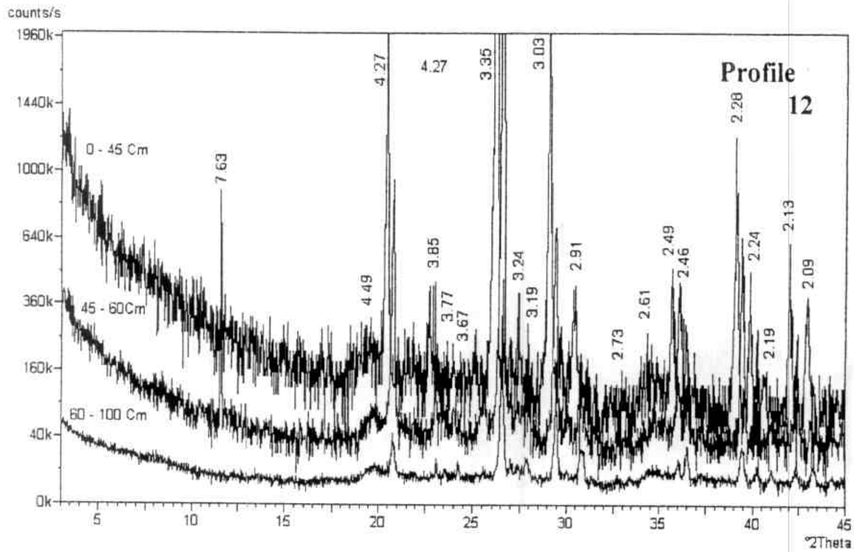


Fig. (26): X-ray diffractograme of the fine sand fraction separated from profiles 6 and 8 of Siwa and Aghormi regions.



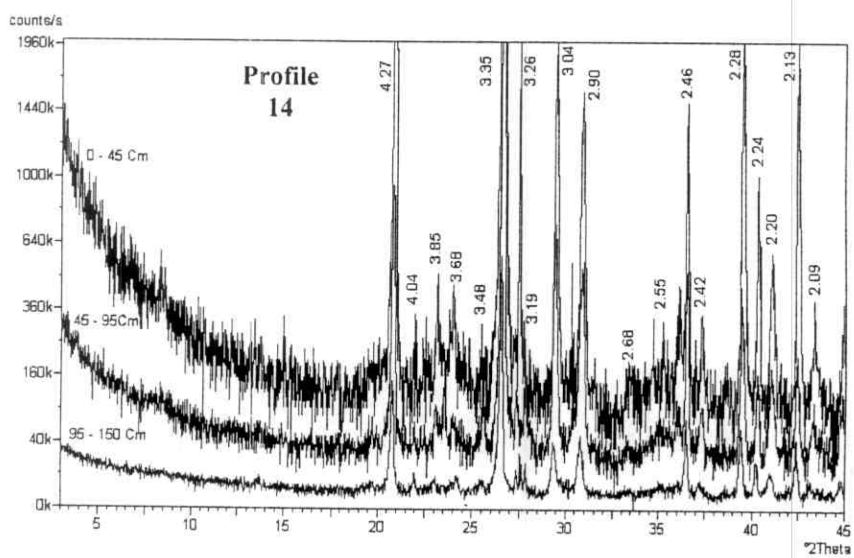


Fig. (27): X-ray diffractograme of the fine sand fraction separated from profiles 12 and 14 of Qureishet and Abu-shrouf regions.

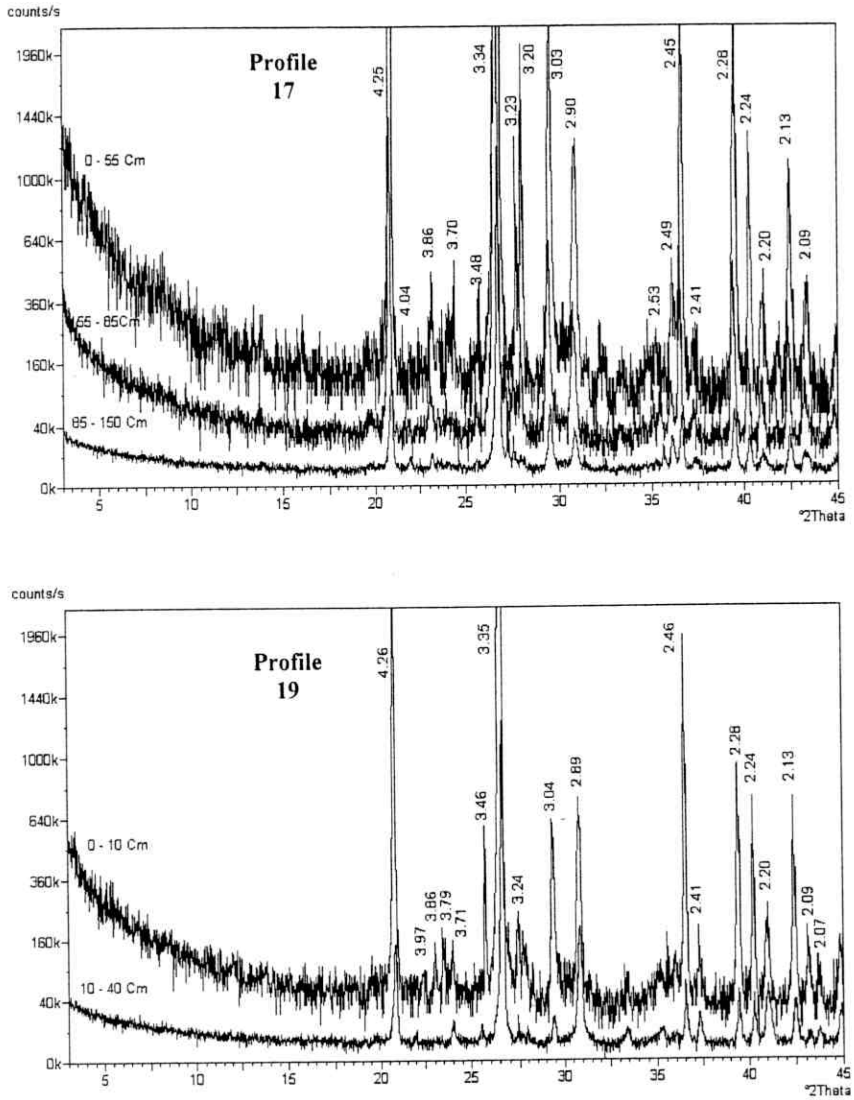


Fig. (28): X-ray diffractograme of the fine sand fraction separated from profiles 17 and 19 of EL-Zeitun and Timeira regions.

Table 22: Soil grades and ratings according to classifications of "land capability" by Storie (1964) and Sys(1991):

Grade	Rating (%)
(I) Excellent soils	100-80
(II) Good soils	79-60
(III) Fair soils	59-40
(IV) Poor soils	39-20
(V) Very poor soils	19-10
(VI) Non- agricultural soils	Less than 10

Application of the capability index for the studied soil profiles is presented in **Table 23**.Soil properties upon which land capability grade was assessed relate to the top soil. The results reveal that the studied soil profiles are placed between grade II (good soils) and grade VI (non–agricultural soils).

Table 23: Soil property ratings according to Sys (1991) with modification .

Factor	Soil property	Rating
A	**quality of irrigation water**	
	Fresh water, low-salintis water <500 mg/L	100
	Slightly saline 1000 mg/L	90
	Water of < 2000 mg/L	80
	Water of 2000 -4000 mg/L	60
	Water of 4000-5000 mg/L	40
	Water of >5000 mg/L	20
B	**Texture grade**	
	L, SiL, SCL, SiCL, CL	100
	Si	90-95
	LS, SC	80-85
	(fine sand), SiC	60-75
	CS (coarse sand)	40-55
C	**Soil profile depth (cm)**	
	> 120	100
	120-90	100-90
	90-60	90-70
	60-30	70-40
	<30	<40
D	**Wetness (drainage conditions)**	
	Well drained	100
	Moderately drained	95-85
	Imperfectly drained	85-75
	Poorly drained	75-45
	Very Poorly drained	45-25
E	**Soil salinity level (dS/m of saturation exteact)**	
	<4	100
	4-8	95-85
	8-16	85-45
	>16	<45

Table 23: Cont.

Factor	Soil properties	Rating
F	**Sodicity (expressed in terms of ESP)**	
	<10	100
	10-15	95-85
	15-30	85-75
	30-50	75-55
	>50	<50
G	**Calcareousness (assessed from carbonate %)**	
	<5	100
	5-10	95-90
	10-20	90-75
	20-50	75-40
	>50	<40
H	**Gypseferousness (assessed by gypsum %)**	
	<3	100
	3-10	95
	10-15	85
	15-25	75
I	**Slope %**	
	Flat or almost flat (0-2 %)	100
	Undulating (2-8 %)	95-90
	Rolling (8-10 %)	90-85
	Hilly (16-30 %)	85-70
	Steep (30-45 %)	70-35
	Very steep (>45 %)	<35
J	**Erosion**	
	Wind erosion	
	None	100
	Slightle	95-90
	Moderate	90-75
	Severe	75-20
	Water erosion	
	None	100
	Slighte	95-90
	Moderate	90-75
	Severe	75-40
	Very severe	40-10

Table 24: Land capability classification of soils of Siwa oasis.

Region	Profile No.	Topographic (A)	Wetness (B)	Texture (C)	Soil depth (D)	$CaCO_3$ (%) (E)	Gypsum (%) (F)	EC dS/m (G)	ESP (H)	Capability Index*	Grade symbol	Indication
El-Maraqui	1	100	85	100	100	80	100	87	100	59.2	III	Fair soils
	2	100	85	100	100	60	100	90	100	45.9	III	Fair soils
Khamisa	3	100	85	100	85	75	100	45	75	18.3	V	Very poor soil
	4	100	85	70	100	95	100	100	100	56.5	II	Good soil
	5	100	85	100	100	90	100	87	100	66.6	II	Good soil
Siwa	6	100	85	100	85	45	100	85	100	20.7	IV	Poor soils
	7	100	85	100	100	80	100	80	100	54.4	III	Fair soils
Aghormi	8	100	85	100	100	65	100	50	100	27.6	IV	Poor soils
	9	100	75	100	85	60	100	80	100	30.6	IV	Poor soils
	10	100	85	40	100	80	100	80	100	21.8	IV	Poor soils
	11	100	85	40	100	80	100	100	100	27.2	IV	Poor soils
Qurei-shet	12	100	75	40	100	40	100	100	100	12.0	V	Very Poor soils
	13	100	85	80	100	90	100	85	100	52.0	III	Fair soils
Abu-shrouf	14	100	85	100	100	75	100	90	100	57.4	III	Fair soils
	15	100	75	100	100	85	100	70	90	40.2	III	Fair soils
El-Zeitun	16	100	85	100	100	85	100	65	90	42.3	III	Fair soils
	17	100	85	100	100	50	100	45	85	16.3	V	Very Poor soils
Timeira	18	100	35	100	50	40	100	90	100	6.3	VI	Non agricultural soils
	19	100	35	100	40	80	100	45	50	2.5	VI	Non agricultural soils

* Capability index is a product of multiplication of A/100x B/100x C/100x D/100x E/100x F/100x G/100x H/100

1- Soils of grade (II) "Good soils":

The soils of grade II are represented by soil profiles which belong to the different regions soil as follows; 4 and 5 (Khamisa region soil). These soils are affected by moderate to severe limitations. The dominant limitations are salinity and sodicity, while the minor limitations are texture and calcareousness.

2-Soils of grade (III)"Fair soils":

The soils of this grade are represented by twelve soil profiles which belong to the different regions as follows; 1, and 2 (El-Maraqui, 7 (16(i.e.Qureishet, Abu-shrouf and El-Zeitun regions).These soils have moderate limitations which are different in their kind and degree. In general, four different limitations are recognized. I.e. texture, sodicity mainly, with minor limitations of salinity and calcareousness.

3-Soils of grade (IV)"poor soils":

The soils of grade IV are represented by soil profiles which belong to the different regions soil as follows; 6 (Siwa region soil); 8, 9, 10 and 11(Aghormi region soil). These soils are affected by moderate to severe limitations. The dominant limitations are salinity and sodicity, while the minor limitations are texture and calcareousness

4-Soils of grade (V) "Very poor soil":

The soils of this grade are represented by profile of 12 (Qureishet region) and 17 (Timeira-region soil).These soils are affected by very severe limitations of salinity and sodicity; long with texture and calcareousness are the minor limitations.

5-Soil of grade (VI) "Non-agricultural soils":

This grade is represented by profile 18, and 19, of Timera region soils. These soils have many severe limitations including salinity, sodicity, calcareousness, texture depth and gypseferousness.

4.16: Macro-and micro-nutrients in soils of Siwa and their relationships with silt and clay mineralogy of the soil as well as some other parameters.

A number of such parameters each of which was considered as the independent "x" variable were correlated with each of the 7 nutrients of N, P, K, Fe, Mn, Zn, and Cu, each of which being as the dependent "y" variable. Statistical correlation /regression analyses were performed on data of the study using the computational analyses cited by **Gomez and Gomez (1983)**.Computations of simple and multiple as well as stepwise linear regression correlation analyses were done.

4.16.1: Simple correlation:

This procedure was carried out to relate 4 soil parameters (one at a time; each considered as x) with each of the plant nutrients (each considered as y). Such procedure illustrates the status of the concerned nutrient (y) as affected by each of the 4 soil parameters (x). Correlations were done and the values of the correlation coefficient (r) and the equations are given. In the current study, only results which gave significant correlations are presented (**figs 29 to 38 and Table 25)**.The appendix shows the complete correlation matrix. The level of significance for r is denoted as: * significant i.e. at 5% level,

Table 25: Correlation coefficient (r) values relating content of clay (cl), silt (si), total $CaCO_3$ (tl) and active $CaCO_3$ (al) with N, P, K, Fe, Mn, Zn and Cu in Siwa soils.

(A): r values

Variable (y)	Variable (x)			
	Clay (cl)	Silt (si)	Total $CaCO_3$(tl)	Active $CaCO_3$(al)
Total-N	- 0.122	- 0.043	- 0.122	0.089
Available-N	0.137	-0.239*	0.116	0.094-
Total-P	0.429**	0.474**	0.303*	0.348**
Available-P	0.353**	0.08	0.255*	0.214
Total-K	0.667**	0.591**	0.500**	0.390**
Available-K	0.290*	0.498**	0.123	0.222
Total-Fe	0.356**	0.541**	0.315*	0.288*
Available-Fe	0.071	- 0.242*	0.01	0.056
Total-Mn	0.312*	0.694**	0.309*	0.342**
Available-Mn	0.438**	0.292*	0.549**	0.446**
Total-Zn	0.095	0.083	0.063	0.122
Available-Zn	0.225	-0.057	0.131	0.309*
Total-Cu	0.232*	0.071	0.202	0.249*
Available-Cu	0.592**	0.051	0.453**	0.201

(1) Levels significant correlations * 5 % and ** 1 %.
(2) Available –N extracted by KCl; determined by Kiel dahl; Available P, K, Mn, Zn, and Cu extracted by AB-DTPA "Ammonium bicarbonate –DTPA".

(B): A brief summary of the simple correlation results.

"relating each of y and x parameter ".

Y parameter of Nutrient	X parameters relating with total forms of nutrients				X parameters relating with available forms of nutrients			
	cl	si	tl	al	cl	si	tl	al
N	ns	ns	ns	ns	ns	-*	ns	ns
P	**	**	*	**	**	ns	*	ns
K	**	**	**	**	*	**	ns	ns
Fe	**	**	*	*	ns	-*	ns	ns
Mn	*	**	*	**	**	*	**	**
Zn	ns	ns	ns	ns	ns	ns	ns	*
Cu	*	ns	ns	*	**	ns	**	ns

* at 0.05 level

** at 0.01 level

ns non –significant

cl. clay ; si. Silt; tl. Total lim; al. active lime.

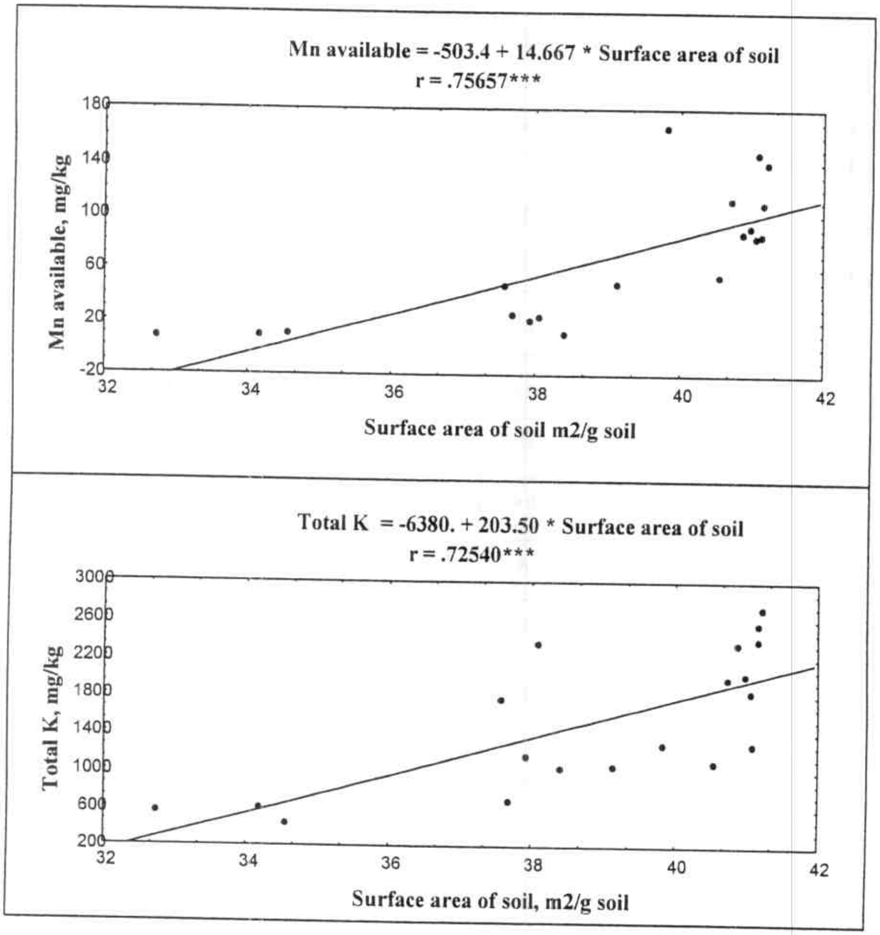


Fig. (29): Relationship between surface area of soil and both of Mn available and total K.

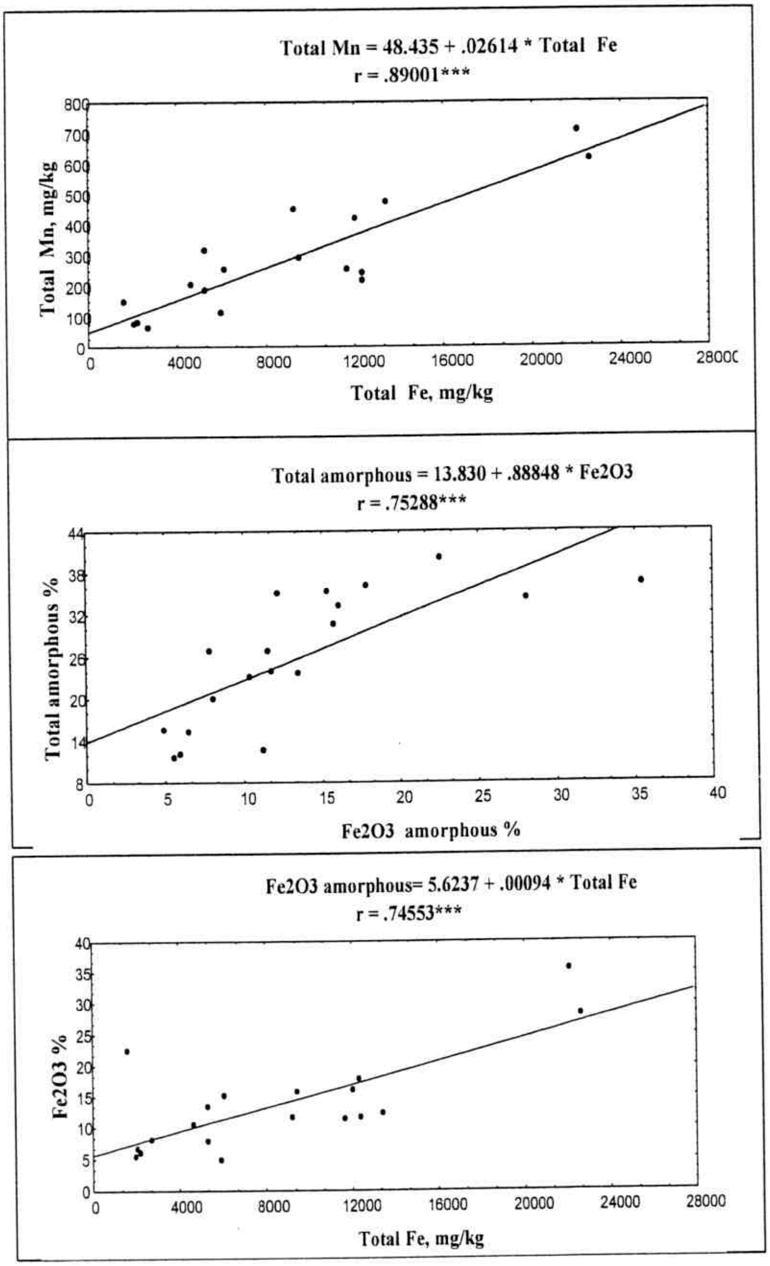


Fig. (30): Relationship between both of total amorphous % and F_2O_3 amorphous %, F_2O_3 % and total Fe, and total Mn and total Fe.

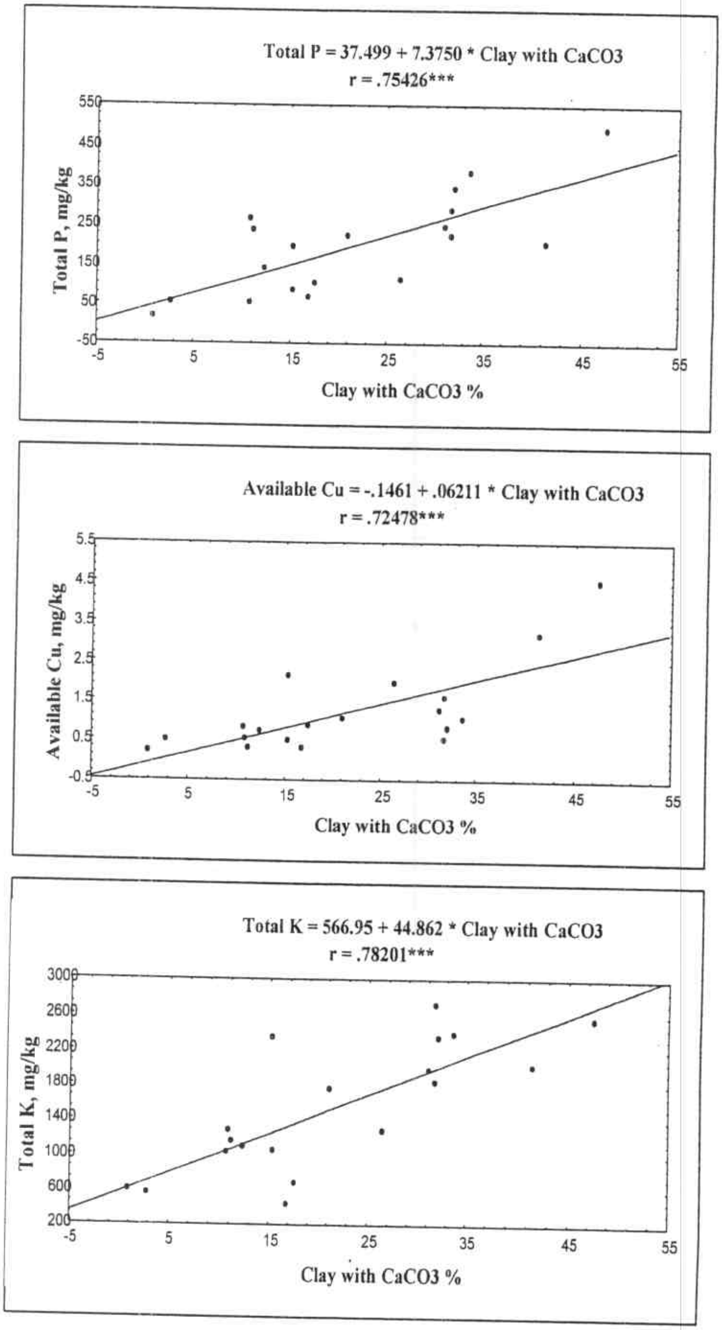


Fig. (31): Relationship between clay with $CaCO_3$ and both of total P, available Cu and total K.

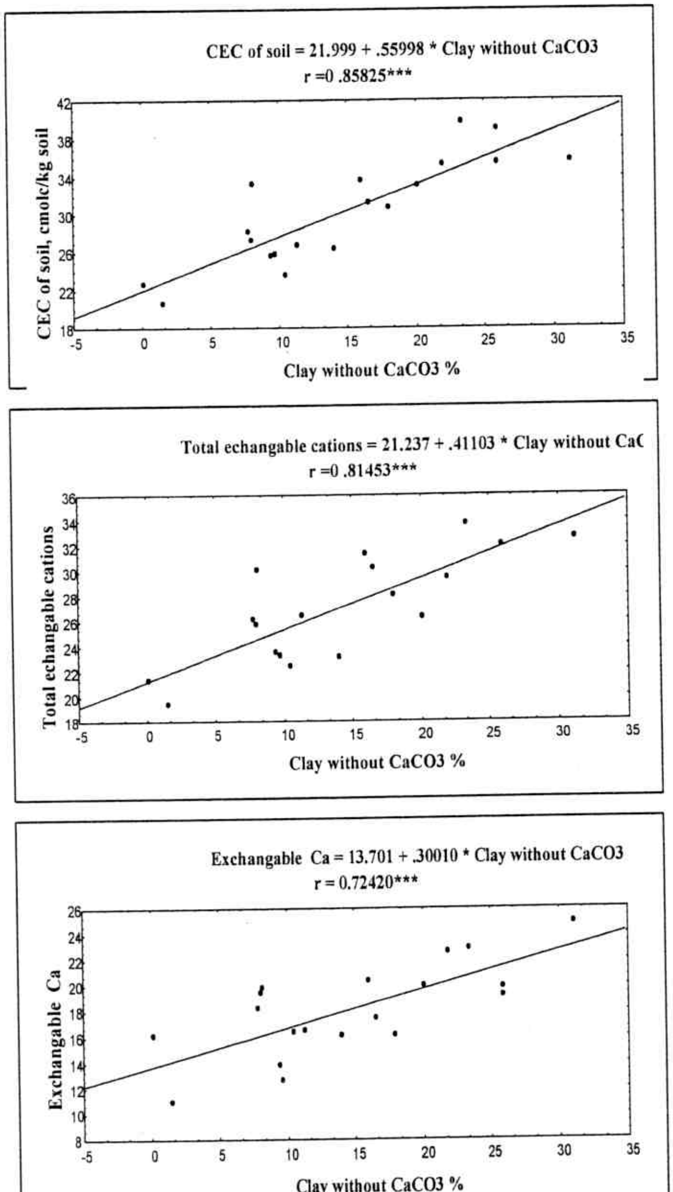


Fig. (32): Relationship between clay without $CaCO_3$ %and both of exchangeable Ca, total exchangeable cations and CEC of soil.

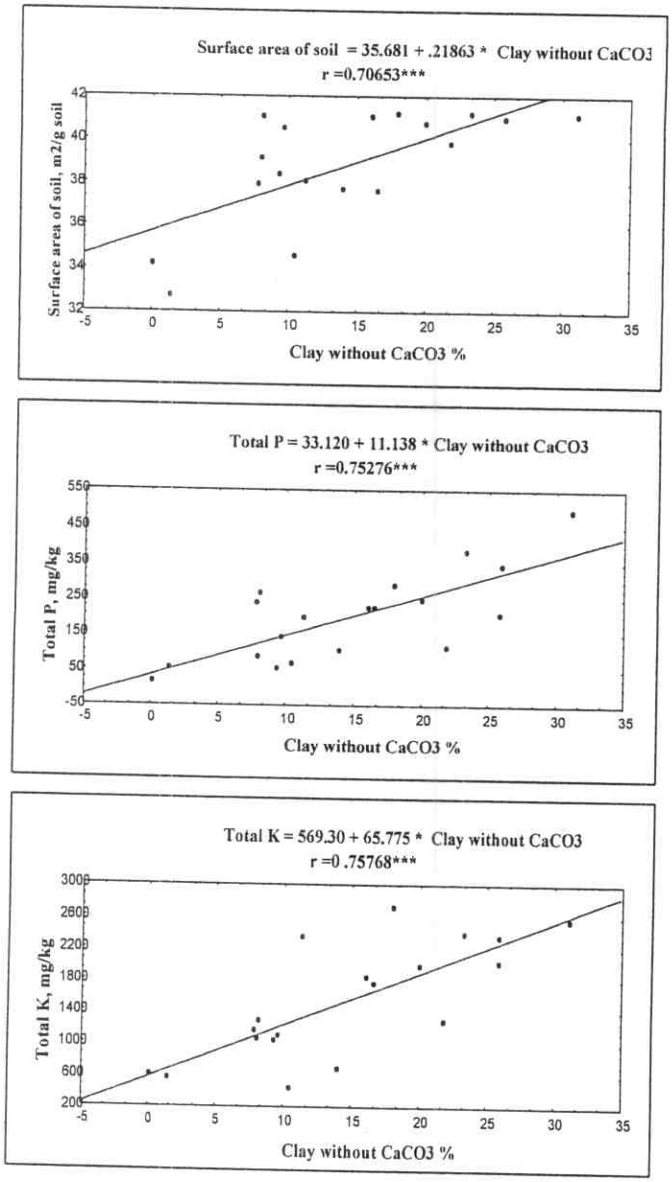


Fig. (33): Relationship between clay without Ca CO_3 % and surface area of soil, total K and total P.

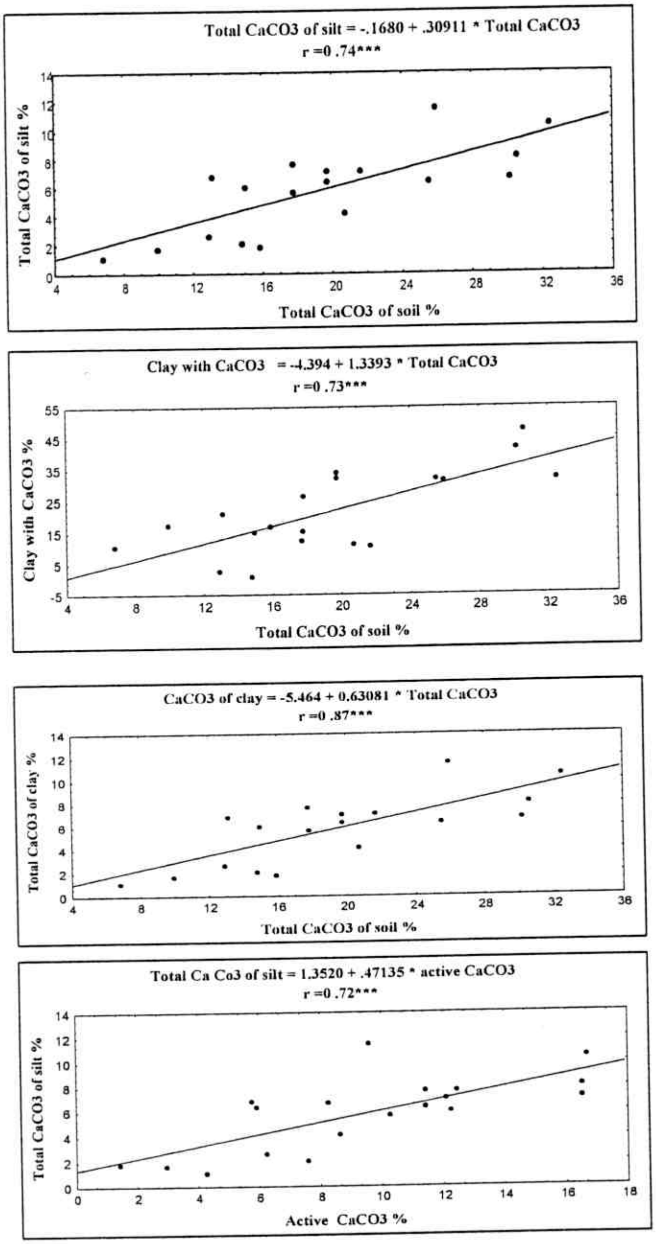
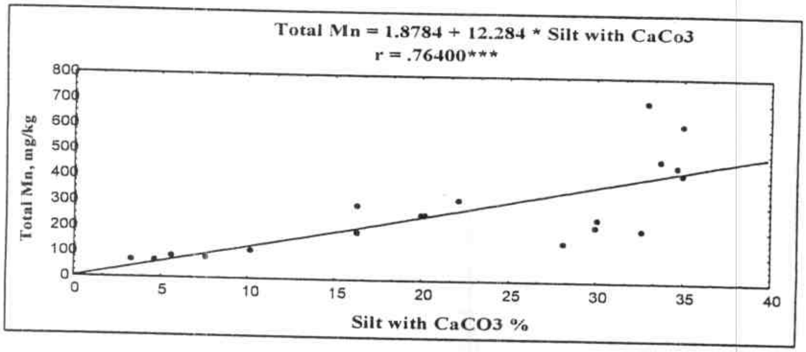
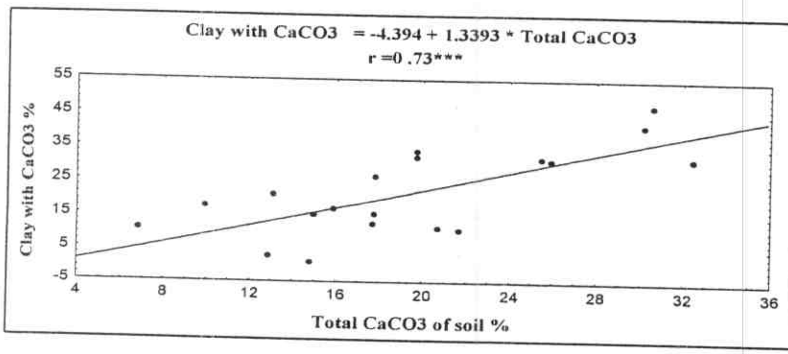


Fig. (34): Relationship between total $CaCO_3$ of silt and both of active $CaCO_3$ and total $CaCO_3$ of clay, and between total $CaCO_3$ of soil and both of clay with $CaCO_3$ and clay with $CaCO_3$.





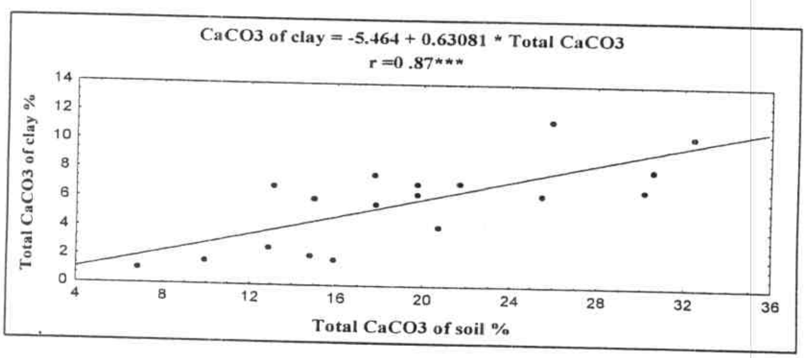
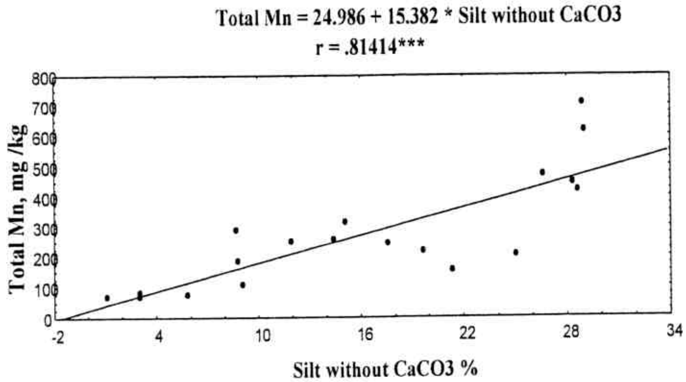


Fig. (35): Relationship between total $CaCO_3$ of soil and both of total $CaCO_3$ of clay and clay with $CaCO_3$. as well as the relation between silt with $CaCO_3$ and total Mn.



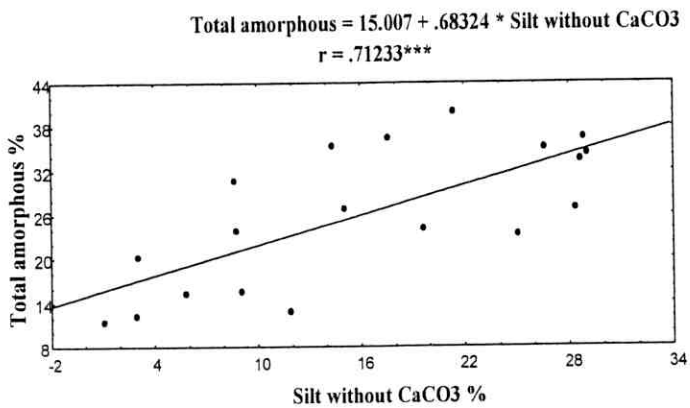


Fig. (36): Relationship between silt without $CaCO_3$ and both of total Mn and total amorphous %.

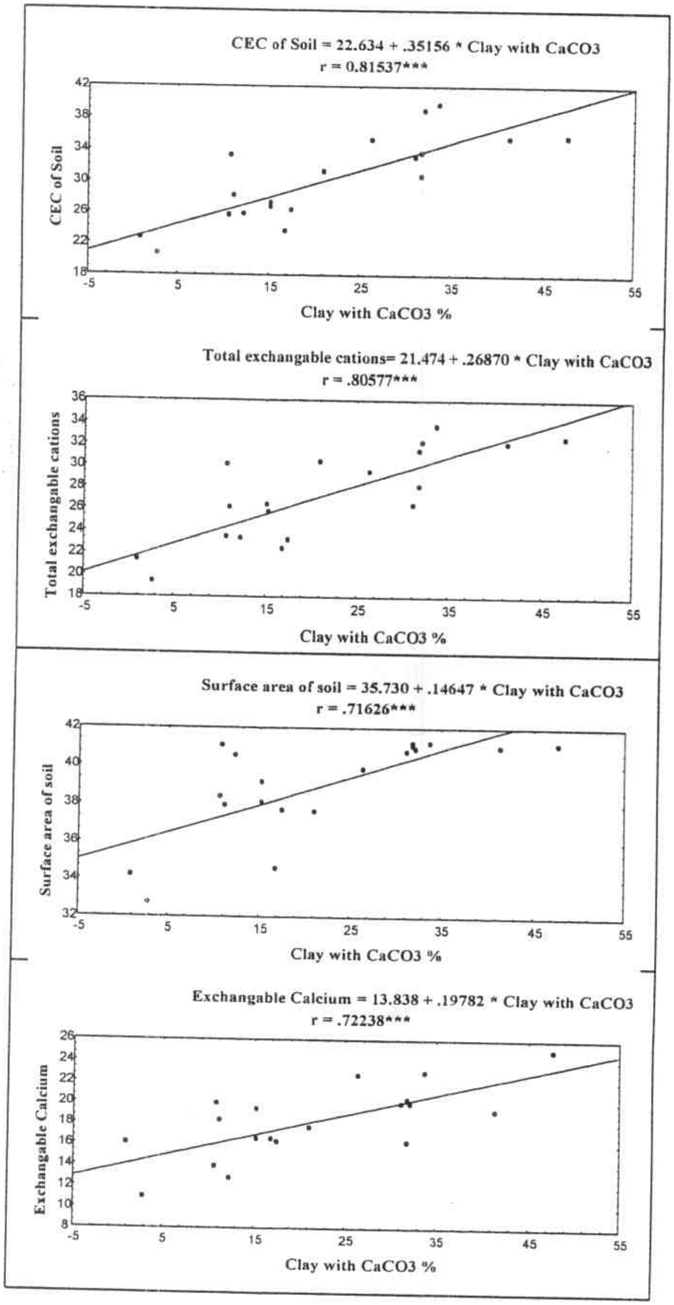


Fig. (37): Relationship between clay with $CaCO_3$ and both of exchangeable Ca, surface area of soil, total exchangeable cations, CEC of soil.

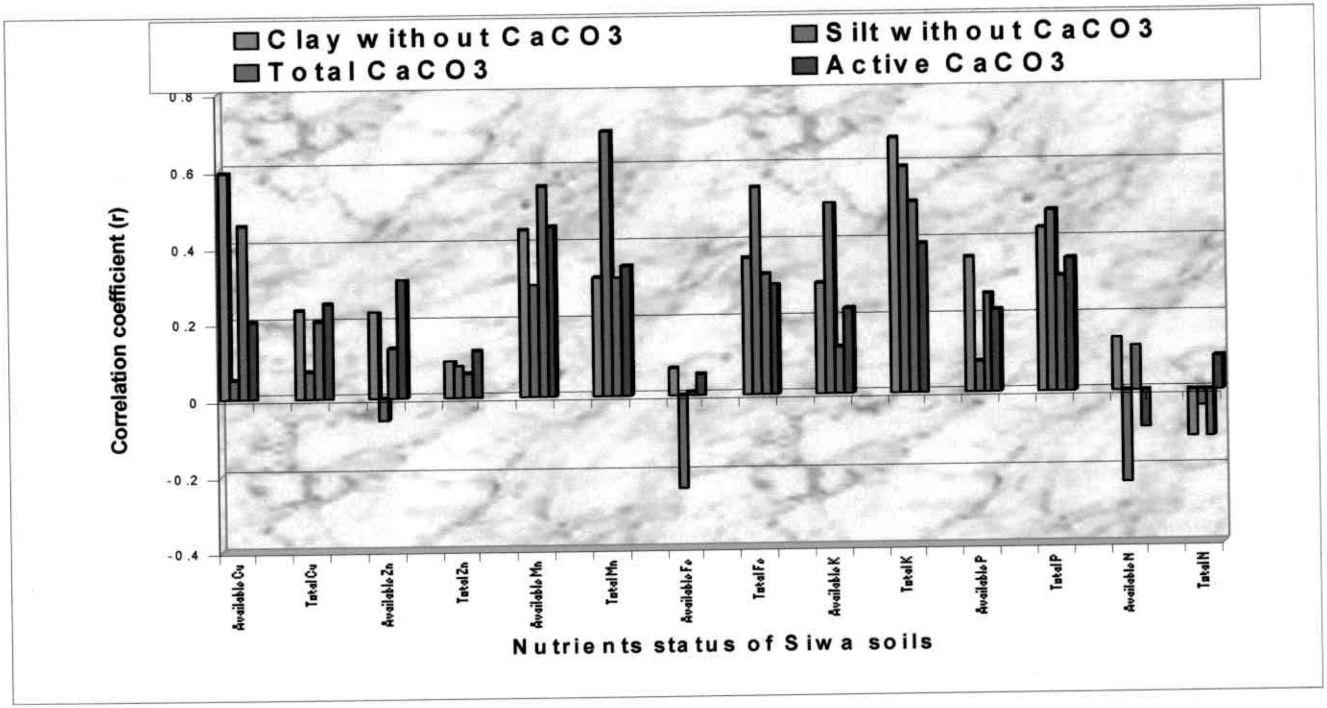


Fig. (38): Values of correlation coefficient (r) relating each of soil clay, silt and calcium carbonate contents with each of the macro-and micro-nutrient in soils of Siwa.

: highly significant i.e. 1%; and *: very highly significant i.e. 0.1% level). The simple correlation executed relating clay, silt and $CaCO_3$ to nutrients in soil will be discussed.

I: Available nutrients:

Clay correlated positively " with P**, K*, Mn** and Cu**, whereas silt correlated positively with K** and Mn*; but negatively with N* and Fe*. Total $CaCO_3$ correlated positively with P*, Mn** and Cu**. Active $CaCO_3$ correlated positively with Mn** and Zn*.

II: Total nutrients:

Clay correlated positively with P**, K**, Fe**, Mn*, and Cu*. Silt correlated positively with P**, K**, Fe** and Mn**. Total $CaCO_3$ correlated positively with P*, K**, Fe*, Mn*. Active $CaCO_3$ correlated positively with P**, K**, Fe*, Mn** and Cu*.

III: Overview on relationships of soil clay, silt and $CaCO_3$ with contents of macro-and micro-nutrients in soil:

From the simple correlations performed on the simple relationship between each of clay, silt and $CaCO_3$ contents with each of the macro- and micro-nutrients, it could be concluded that silt in particular showed strong positive relations particularly regarding the totals of each of P, K, Fe and Mn. Clay followed silt. Silt fraction of most soil is usually rich in feldspars which represent a significant store for nutrients **(Foth 1978)**. Clay and silt as well as $CaCO_3$ contents have direct and indirect bearing on the contents of macro- and micronutrients in the soil. Aspects such as structural constitution of these components and properties such as adsorption, fixation, and complexation with nutrients **(Bolt and Bruggenwert 1978)** participate in this concern. There was a case where silt correlated negatively with available N and available Fe indicating a possible negative effect of high silt contents on N and Fe availability. Effect of $CaCO_3$, particularly the active part of it shows a general close positive relationship with a majority of total and available forms of nutrients except nitrogen and both available potassium and iron and total Zinc. Although calcium carbonate is not considered a reservoir for nutrients (except for Ca and to some extent Mg), it many be adsorbing or complexing with some nutrients such as P, K, Fe, and Mn.

4.16.2: Multiple (MC) and stepwise (SC) corrolations:

These procedures were carried out to relate 5 soil parameters with each of the P, K, Fe, Mn Zn, and Cu nutrients.

I: Multiple correlations:

Multiple correlations relate all 5 parameters. They represent the independent parameters illite "il" x1, smectite "sm" x2, kaolinite "ka" x3, active $CaCO_3$ "al" x4, and total $CaCO_3$ "tl" x5with each of the plant nutrients (considered as y). Such statistical technique gives a computed estimate of contents of each plant nutrient (y through the knowledge of the x parameters. An equation is obtained in this respect. Taking available K and its relations with the 5 soil parameter as an example, such an equation is as follows:

Av. K (y) =597.3+14.1il (x1)–5.3sm (x2) +5.2 ka(x3)–17.9al(x4) +0.2tl (x5).

R^2 (coefficient of determination) = 0.153

R (multiple correlation coefficient) = 0.532

The R^2 measures the contribution of these 5 parameters to the variation in a vailable K (y). In this example R^2 = 0.153 which means that 15.3 % of the variation in av. K is explainedby the linear function of the 5 parameters.

II: Stepwise correlation: The stepwise regression includes only the "x" parameters that contribute significantly to the variation of "y"; and excludes those not contributing significantly in the equation; in the same example the stepwise equation is as follows:

Available K "y" =597.3 – 0.2 il"x1" + 0.3 al "x5".

This means that it is illit and active $CaCO_3$ which contribute significantly to variation available K, while others do not.

III: Full results for macro-and micro-nutrients.

The full results of the multiple and stepwise equations are as follows:

1-Potassium:

Total K (tot.k)

Multiple:

Tot.k = 1849.9 – 22.1 il -8.8 sm + 4.0 ka – 57.3 al + 31.7 tl (R= 0.391, R^2 = 0.153).

Stepwise:

Tot.K = 1849.9 – 0.4 al + 0.4 tl.

Indicating the importance of $CaCO_3$ contents (active and total) in the contribution to total K in soil.

Available K: (av K):

Multiple:

Av.(K) = 597.3 – 14.1 il – 5.3 sm + 5.2 ka – 17.9 al + 0.2 tl. (R 0.532, R^2 =0.283).

Stepwise:

Av.(K) = 597.3 0.2 il + 0.3 al.

Indicating the importance of illite and active $CaCO_3$ in the contribution to available K in soil.

2-phosphorous:

Total P (tot. P)

Multiple:

Tot. P=515.9–3.0il+ 3.2 sm – 4.6 ka – 11.5 al - 15 tl (R= 0.533, R^2= 0.284).

Stepwise:

Tot. P = 515.9 – 0.5 ka - 0.4 al.

Indicating the importance of kaolinite and (active $CaCO_3$ contents) in the contribution to total P in soil.

Available P: (av P):

Multiple:

Av. (P) = 2.0 + 0.1 il + 0.1 sm + 0.1ka + 0.5al - 0.01 tl. (R= 0.661, R^2 = 0.437).

Stepwise:

Av. (P) = 2.0 + 0.2il + 0.4 ka + 0.6 al.

Indicating the importance of illite, kaolinite andactive $CaCO_3$ in the contribution to available K in soil.

3-Iron:

Total Fe (tot. Fe)

Multiple:

Tot. Fe = 6024 + il + 295 sm + 91 ka – 84.5 al + 139.9 tl (R= 0.352, R^2 = 0.124).

Stepwise:

Tot. Fe = 6024 – 0.3 sm + 0.2 ka.

Indicating the importance of smectite and kaolinite in the contribution to total Fe in soil.

Available Fe: (av Fe):

Multiple:

Av. (**Fe**) = 95.6 + 0.7 il + 5.7 sm - 0.3 ka - 0.1 al – 2.8 tl. (R = 0.422, R^2 = 0.178).

Stepwise:

Av. (**Fe**) = 95.6 + 0.4 sm – 0.4 tl.

Indicating the importance of smectite and total $CaCO_3$ in the contribution to available Fe in soil.

4-Manganes:

Total Mn (tot. Mn)

Multiple:

Tot. Mn = 523.7 – 13.6 il – 2.7 sm – 1.6 ka – 8.9 al + 0.7tl (R = 0.525, R^2 =0.276.

Stepwise:

Tot. Mn = 523.7 – 0.4 il – 0.2 ka – 0.3al.

Indicating the importance of illite and kaolinite in the contribution to total Mni n soil.

Available Mn: (av Mn):

Multiple:

Av. (Mn) = 66.8 – 2.7 il – 1.4 sm + 0.3 ka - 1.1 al + 2.8 tl. (R = 0.426, R^2 =0.181).

Stepwise:

Av. (Mn) = 66.9 + 0.5 tl.

Indicating the importance of total $CaCO_3$ in the contribution to available Mn in soil.

5-Zinc:

Total Zn (tot. Zn)

Multiple:

Tot. **Zn** = 51.3 – 1.4 il + 0.3 sm – 0.02 ka – 0.9 al + 0.2 tl (R= 0.339, R^2 = 0.115).

Stepwise:

Tot. **Zn** = 51.3 – 0.3 il – 0.2 al.

Indicating the importance of illite and active $CaCO_3$ in the contribution to total **Zn** n soil.

Available Zn: (av Zn):

Multiple:

Av. (**Zn**) = 2.9 + 0.2 il + 0.2 sm + 0.01ka + 0.05 al – 0.13tl. (R =0.757, R^2 =0.573).

Stepwise:

Av. (Zn) = 2.9 + 0.4 il – 0.8 tl.

Indicating the importance of illite and total $CaCO_3$ in the contribution to available Zn in soil.

6-Copper:

Total Cu (tot. Cu)

Multiple:

Tot.Cu=4.6+ 0.4 il – 0.01 sm – 0.002 ka + 0.015 al – 0.023 tl (R =0.436, R^2=0.190).

Stepwise:

Tot. **Cu** = 4.6 + 0.4 il.

Indicating the importance of illite in the contribution to total Cu n soil.

Available Cu: (av Cu):

Multiple:

Av.(Cu) =1.4–0.1 il + 0.04 sm +0.01 ka – 0.12 al + 0.04 tl. (R 0.677, R^2 = 0.458).

Stepwise:

Av. (Cu) = 1.4 – 0.3 il + 0.2 sm + 0.2 ka – 0.6 al + 0.4 tl.

Indicating the importance all variable in the contribution to available Cu in soil.

III: Overview on relationships of clay mineralogy and soil $CaCO_3$ with content of macro- and micro-nutrients in soil:

The effect of clay mineralogy on contents of total and available nutrients was mainly through illite in the first place; kaolinite showed less contribution; smectite exhibited an effect only regarding Fe. This indicates the importance of illite as a reservoir for K, P, and trace elements in particular. In has a strong affiliation to available K, P, and Zn in particular. Being are of the mica group it contains K and it also fixes K from applied K fertilizers **(Deer et al 1985).** Kaolinite showed a particular broad association with total as well as available P beside total Fe and Mn. This particular mineral possesses anion exchange phenomena and can adsorb and fix phosphates, and could also accommodate iron and manganese **(Marshall 1964 and Deer et al 1985).**With regard to the effect of $CaCO_3$, it was the active from which showed a major contribution in the correlation with nutrients in soil particularly P and K where it participated in their total as well as available forms. Contents of total $CaCO_3$ showed their effect mainly on available Fe, Mn, and Zn. Such strong association of $CaCO_3$ with nutrients in the soil is a manifestation of its adsorption and complexation characteristics with soil plant nutrients **(Bolt and Bruggenwert 1978).**