Values of kurtosis indicate that the soils are characterized by alternative pattern, i.e., leptokurtic, mesokurtic, very leptokurtic, extermely leptokurtic and platy kurtic. This pattern suggests a combination of water and wind actions in the formation of the soils with leptokurtic or mesokurtic values, water action for platy kurtic and wind action for very or extremely leptokurtic. This suggestion dose not coincide quite well with sorting values.

Soils of playa :

Statistical size parameters illustrated in Table (27), and cumulative curves of the soils of playa, given in Fig.(9), show that the calculated Mz ø values are 2.57 ø and 2.65 ø for the topsoil (0—15 cm) and substratum (60—150 cm) in profile No.8, indicating fine sand, while they are 1.62 ø and 1.63 ø for the subsoil (15—60 cm), indicating medium sand.

Sorting values range from 1.93 ø to 2.53 ø indicating poorly sorted to very poorly sorted sediment, which suggest that water is the main action responsible for transportation and deposition of these soils.

Values of skewness are 0.16 ø for the surface layers (0—40 cm),indicating fine skewed deposits, 0.04 ø for the subsoil (40—60 cm) indicating near symmetrical, and –0.3 ø for the deepest layers (60—150cm), indicating coarse skewed sediments. That mean the soils have a tail of fineness in the upper layers, and a tail of coarser materials in the deepest layers.

Values of kurtosis range from 0.58 ø to 0.66 ø indicating very platy kurtic and mean that soils are transported and deposited by water action, which coincide quite well with the sorting values, except for the

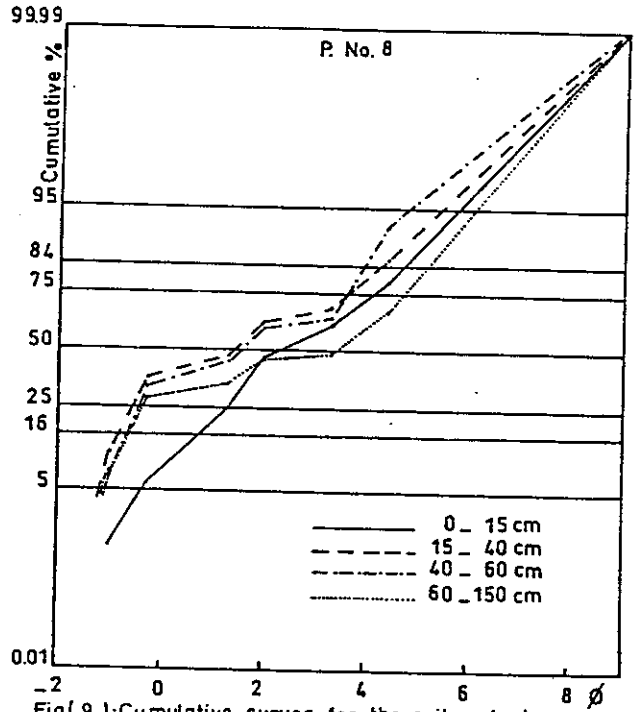


Fig.(9):Cumulative curves for the soils of playa

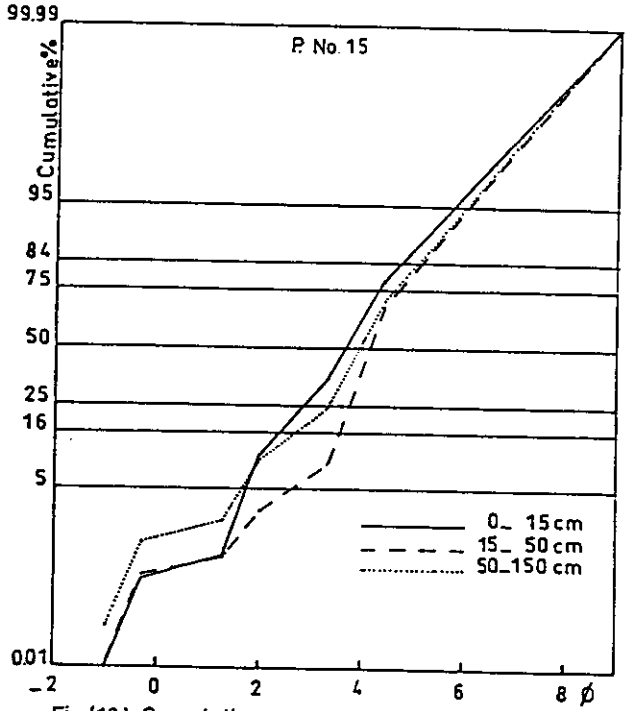


Fig.(10):Cumulative curves for the soils of sabkha

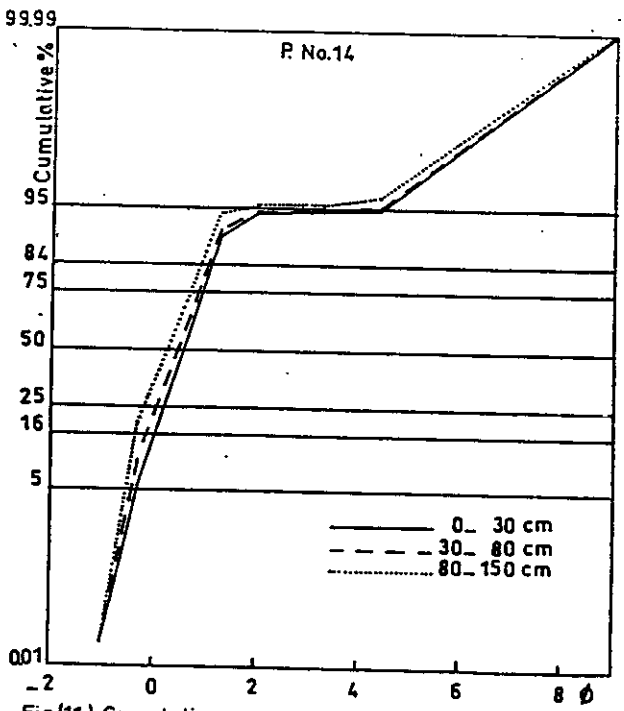


Fig.(11):Cumulative curves for the soils of sand dunes

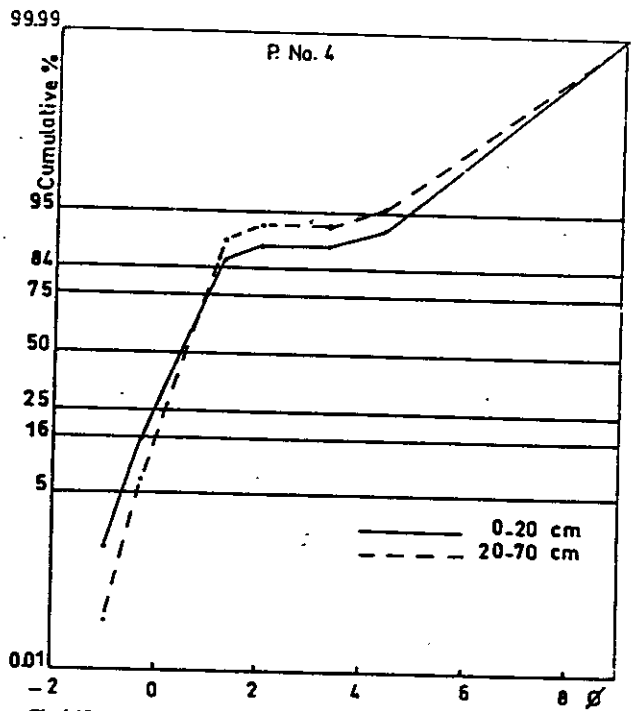


Fig.(12):Cumulative curves for the soils of coastal beach

topsoil where kurtosis is 0.9 ø indicating mesokurtic, which suggests a combination of wind and water in the formation of the topsoil.

Soils of sabkhas :

Computed statistical size parameters of profile No.15, which represents the soils of sabkhas, are given in Table (27), and cumulative curves are illustrated in Fig. (10).

The graphic mean size (Mz ø) of the topsoil (0—15 cm) and the lower part of subsoil and substratum (50—150 cm) range from 3.55 ø to 3.88 ø, indicating very fine sand, while subsoil is 4.28 ø, indicating coarse silt.

Sorting values of the topsoil and lower part of subsoil and substratum range from 1.19 ø to 1.25 ø, indicating poorly sorted sediments, and suggest that water is the main action responsible for transportation and deposition of these soils, while sorting value of the subsoil is 0.92 ø, indicating moderately sorted materials, which suggests a combination of water and wind actions in the formation of these soils.

Skewness values of the topsoil and lower part of subsoil and substratum range from –0.03 to 0.01 ø indicating near symmetrical, while subsoil has a skewness value of 0.18 ø, indicating fine skewed sediments.

Values of kurtosis range from 1.09 ø to 1.49 ø, indicating mesokurtic and leptokurtic. This suggests the involvement of water and wind actions in the formation of these soils. This suggestion dose not coincide quite well with sorting values.

Soils of oolitic sand dunes :

Computed statistical size parameters of profile No.14, which represents the soils of oolitic sand dunes, are given in Table (27), and cumulative curves are illustrated in Fig.(11).

The graphic mean sizes (Mz ø) range from 0.27 ø to 0.57 ø, indicating coarse sand throughout the different profile layers.

Sorting values range from 0.67 ø to 0.98 ø, indicating moderately sorted to moderately well sorted sediments, which suggest a combination of water and wind actions responsible for transportation and deposition of the soil materials for the layers 0—80 cm, while wind is the main action for soil formation of the layer 80—150 cm.

Skewness values range from 0.2 ø to 0.34 ø, indicating fine to strongly fine skewed sediments.

Values of kurtosis range from 1.13 ø and 2.6 ø, indicating leptokurtic and very leptokurtic. This means that the topsoil and subsoil from 0 to 80 cm (very leptokurtic) are formed under wind action, while the depth 80 – 150 cm is formed under a combination of wind and water actions.

Soils of coastal sand beach :

Statistical data of grain size parameters of profile No.4, which represents the soils of coastal sand beach are given in Table (27) and illustrated in Fig.(12). Results show that the graphic mean size (Mz ø) ranges from 0.47 ø to 0.55 ø, indicating coarse sand. Sorting values range from 0.96 ø to 1.2 ø, indicating poorly sorted in the topsoil and moderately sorted in the subsoil, which suggest that topsoil sediments

are transported and deposited under water action, while subsoil material are formed under a combined effect of both wind and water. Skewness values range from 0.3 ø to 0.32 ø, indicating fine to strongly fine skewed and the soils have tails of fineness.

Values of kurtosis range from 2.25 ø to 2.63 ø, indicating very leptokurtic. This suggest that soils are transported and deposited under wind action.

4.4.Soil formation:

4.4.1 Soil forming factors:

Parent rock transformed to parent material by physical and /or chemical weathering. The weathered material is turned into soil by the operation of certain factors and processes. The soil forming factors are : climate (temperature and precipitation), biosphere, parent material, topography, and time.

The climatic factors prevalinig in the stdied area are temperature, precipitation, and wind. The high temperature, wind, and low precipitation are affecting evaporation and transpiration which resulting in formation of gypsic and salic horizons.

The effect of biosphere, especially the natural vegetation, is negligible. The parent material has a pronounced influence on the properties of soils of the studied area, i.e., high calcium carbonate content, coarse texture, amount of gravel and gypsum content.

Topography modifies soil profile development by influencing climate, erosion and lateral movement of material in solution or suspension.

The effect of time on soil formation is frequently obscured because the past climate is different from the present. In such a case, it is difficult to establish whether the soils are different as a consequence of time or of climate.

4.4.2.Soil forming processes:

4.4.2.1. Salinization and salic horizon:

Salinization is the accumulation of soluble salts in the soil profile, whether by natural processes or as a result of irrigation. The ground water table or the capillary zone above it must reach into the soil profile. Salt accumulation is affected by evaporation of water above the capillary zone. Depending on the ground water level , capillaries may reach the surface causing salt to be deposited on top of the soil, as the cases in profile No.15 (sabkha) and proifle No.4 (coastal sand beach), where a thin to thick salt crust is formed on the soil surface. Salt may be precipitated below the surface, as the case in profile No.15, where salt is precipitated in the topsoil and subsoil. Most of the studied soils are salt affected where salinity is measured indirectly as the electrical conductivity (EC) of soil paste extract. Salic horizon is observed only in soil profile No.15, where it is 15cm or more thick and has for 90 consecutive days or more per year, in 6 or more years out of 10; electrical conductivity (EC) equal to or greater than 30dS/m in a 1:1 soil

: water extract; and the product of EC in dS/m and thickness in cm equal 900 or more (Soil Survey Staff,1998).

The surface salic horizon (Az) of profile No.15 is 15cm thick, the EC is 136.65 dS/m in a 1:1 soil : water extract, and the product of the EC in dS/m and thickness in cm equal to 2049.75.

The subsoil layer (Cz, 15—50 cm) is 35cm thick, the EC is 100.21 dS/m in a 1:1 soil: water extract, and the product of EC in dS/m and thickness in cm equal to 3507.35. Although the other soils are strongly to extremely saline, they do not meet the requirements for salic horizon.

For example, in playa soils were the EC of the topsoil in a 1:1 soil :water extract was 34.35 dS/m, then the product of EC and thickness (cm) equals 51 5 , such value is less than 900, thus it is not enough to meet the requirements of salic horizon.

4.4.2.2. Gypsification and gypsic horizon :

gypsum rocks in the studied area consist of hydrated calcium sulphate ($CaSO_4.2H_2O$) as in Zayt formation of Upper Miocene in Tertiary age and anhydrite ($CaSO_4$) as in South Gharib formation of the same geological age. During the Pliocene and Pleistocene, the gypsiferous rocks and sediments weathered and eroded. The debris was displaced by aeolian or fluviatile action. In some instances, the gypsum in primary deposits was dissolved and precipitated in younger formations. Sediments with such detrital or precipitated gypsum accumulations are called secondary gypsum deposits, their formation is still continuing (Alphen and Romero,1971).

Gypsum may precipitate, when the capillary fringe of gypsum-bearing ground water is located close to the surface, if evaporation is high.

The parent rocks rich in sulphur compounds, such as pyrite, may produce sulphuric acid upone oxidation, which subsequently reacts with the $CaCO_3$ abundant in the rock.

Gypsum deposits can be either pedogenetic or geogenetic. The translocatin and deposition of gypsum in a soil profile as a result of rainwater or capillary rise and evaporation apparently is a pedogenetic phenomenon, while the formation of the Miocene gypsum deposits is a geogenetic process. Gypsum deposits originating from ground water evaporation may be called hydrogenetic.

Gypsic horizon defined in Soil Taxonomy (Soil Survey Staff,1998) is an illuvial horizon in which secondary gypsum has accumulated to significant extent. A gypsic horizon has the properties of: 15cm or more thick; not cemented or indurated to such a degree that it meet the requirments of a petrogypsic horizon; 5 percent or more gypsum, 1 percent or more by volume secondary visible gypsum; and a product of thickness in cm multiplied by gypsum content percentage of 150 or more.

Gypsic horizon was observed in the soils of old and young alluvial terraces, profile No,1 (upper alluvial deltaic plain) and profile No.8 (playa).

Gypsum was found in the forms of soft dots or segregations, hard concretions or nodules, crystals and hard spongy gypsum.

4.4.2.3. Calcic horizon :

Although the high amount of calcium carbonate in the studied soils, there is no evidence of calcic horizon formation. This is mainly

due to the morphological characteristics of the studied soils did not show any secondary accumulations of calcium carbonate. This is harmony with the openion of Reeuwijk (1984) who pointed out that the low biological activity responsible for CO_2 release, no enough water moving through the soil materials, rise in pH and an increase of Ca^{+2} ion concentration are the main factors responsible for absence of the calcic horizon.

4.4.2.4. Organic matter status :

The organic matter content in the soils of the studied area is very low. It may be due to the scanty natural vegetation, aridic soil moisture regime and hyperthermic soil temperature regime, which would increase the decomposition of organic matter, and consequently decrease its content. The highest value of organic matter content (2.2%) was found in the surface layer (0-15 cm) of profile No.15 which reprsents the soils of sabkha, while the lowest one (0.026%) is found in the subsoil and substratum layers (20-150 cm) of profile No.5 which represents the soils of upper alluvial deltaic plain.

The relatively high amount of organic matter in the topsoil of sabkha is associated with the high salinity of this layer (EC is 136.05dS/m) as compared with the very low value of the layers (20-150cm) in profile No. 5 of the upper alluvial deltaic plain, which have EC of 5.2 dS/m. Afify (1999) stated that it is most probably that the organic matter is party preserved by the salt affect, which minimize the effect of microbial activity for the decomposition of organic matter.

4.5. Soil classification :

A soil classification is an ordering or arrangement of soils and their distribution into groups. Kellogg (1964) defined the purpose of soil classification so as to integrate the knowledge of them in a definite concept and to relate them to one another. Thus, predicting their response to environment.

The Soil Taxonomy System (Soil Survey Staff,1975) and keys to Soil Taxonomy (Soil Survey Staff,1998) were used to classify the soils of the studied area.

Soils are classified from the highest category (orders) down to soil family level, based on presence or absence of the diagnostic horizons and other characteristics, soil texture, soil moisture and temperature regimes, soil characteristics of the control section,i.e., particle size, mineralogy class and soil depth.

Two soil orders were recognized in the area under consideration, i.e., Aridisols and Entisols.

4.5.1. Aridisols order:

These soils have an aridic soil moisture regime, an ochric epipedon, a salic horizon or a gypsic horizon with the upper boundary within 100 cm of the soil surface.

The soils of Aridisols could be divided into two suborders, i.e., Salids and Gypsids.

4.5.1.1. Salids suborder:

Salids are Aridisols which have a salic horizon that has its upper boundary within 100 cm of the soil surface. One great group is

identified under Salids, named Haplosalids. They are not saturated with water in one or more layers within 100cm of the soil surface for one month or more per year. The soils of Haploslids are categorized into Typic Haplosalids subgroup, because they do not have a duripan, petrogypsic, gypsic, or calcic horizon. One soil family is recognized within Typic Haplosalids subgroup, which has fine loamy textural class of control section, carbonatic mineralogy and hyperthermic soil temperature regime. Soils of sabkha which are represented by profile No.15 can be classified into :

***Typic Haplosalids, fine loamy , carbonatic, hyperthermic**.

4.5.1.2.Gypsids suborder :

Gypsids are Aridisols which have a gypsic horizon that has its upper boundary within 100 cm of the soil surface. One great group is identified, named Haplogypsids. Haplogypsids are Gypsids that have only a gypsic horizon, and have not any other dignostic horizon such as petrogypsic, petrocalcic, natric, argillic, or calcic horizon. Within Haplogypsids, two subgroups were recognized, i.e., Leptic and Typic Haplogypsids, each of them has a gypsic horizon that its upper boundary within or below 18 cm of the soil surface for Leptic and Typic, respectively.

Six soil families were found within the two subgroups, they are :

***Typic Haplogypsids, sandy skeletal, gypsic, hyperthermic**.

This soil family is represented by profile No.6 in the old alluvial terraces. The textural class of control section is sandy skeletal, where the texture is sand and the coarse fragments constitute more than 35%. The mineralogy class is gypsic, where the control section has

more than 40% by weight of carbonates (expressed as $CaCO_3$) plus gypsum, and the gypsum is more than 35% of the sum of carbonates and gypsum. The soil temperature regime is hyperthermic, where the mean annual temperature is more than 22C°.

***Typic Haplogypsids, sandy, carbonatic, hyperthermic.**

This soil family is represented by profile No.7 in the old alluvial terraces. The textural class of control section is sandy, where the texture is sand, and the coarse fragments are less than 35%. The mineralogy class is carbonatic, where the control section has more than 40% by weight carbonates plus gypsum, and the carbonates are more than 65% of sum of carbonates and gypsum. Soil temperature regime is hyperthermic, where the mean annul temperature is more than 22C.

***Typic Haplogypsids, sandy skeletal, carbonatic, hyperthermic.**

This soil family is represented by profile No. 1 in the upper part of alluvial deltaic plain. The textural class of control section is sandy skeletal, the mineralogy class is carbonatic, and soil temperature regime is hyperthermic.

***Leptic Haplogypsids, sandy skeletal, carbonatic, hyperthermic.**

This soil family is represented by profile No.9 in the young alluvial terraces. Textural class of the control section is sandy skeletal, mineralogy class is carbonatic,and soil temperature regime is hyperthermic.

***Leptic Haplogypsids, sandy, carbonatic,hyperthermic.**

It is represented by profile No.11 in the young alluvial terraces. Textural class of control section is sandy, mineralogy class is carbonatic and soil temperature regime is hyperthermic.

***Leptic Hapolgypsids, fine loamy, mixed, hyperthermic.**

It is represented by profile No.8 in playa. Textural class of the control section is fine loamy, where the texture of more than half of the control section is sandy clay loam and the clay content is more than 18%. The mineralogy class is mixed because the soils have less than 40% by weight of any single kind of minerals other than quartz or feldspars. Soil temperature regime is hyperthermic.

4.5.2 Entisols order :

These soils have little or no evidence of development of pedogenic horizons. They do not have horizons other than an ochric epipedon.

There are several reasons why horizons have not formed, the time has been too short, the soils are on flood plains that receive new deposits of alluvium at frequent intervals, or the soils are very old, but consist of quartz or other minerals that do not alter to form horizons. Three suborders of Entisols were identified in the studied area :

4.5.2.1 Psamments suborder :

Psamments are Entisols that have less than 35% (by volume) rock fragments and a texture of loamy fine sand or coarser in all layers within the control section for the family particle size class.

Only one great group was identified in the studied area, named Torripsamments, where the moisture regime is torric.

Typic Torripsamments is the only subgroup within the great group Torripsamments. Soils of Typic Torripsamments do not have a lithic contact within 50 cm of the surface, do not have a horizon within 1m of the surface that is >15cm thick and either contains 20% or more durinodes in a nonbrittle matrix or brittle and has firm consistence when moist and dry in all parts of the moisture control section three-fourths or more of the time (cumulative).

One soil family was recognized within this subgroup:

***Typic Torripsamments, carbonatic, hyperthermic.**

Included soil profiles 12 (lower part of alluvial deltaic plain), 14 (oolitic sand dunes) and 4 (coastal sand beach).

Soil profile 12 consists of alluvial deposits which transported and deposited by water, while profiles 14 and 4 are formed by wind action and wind - marine action, respectively.

The area of profile No.12 is cultivated with olives, sand dunes and coastal beach are baren.

4.5.2.2 Fluvents suborder :

Fluvents are Entisols that do not have a densic, lithic, or paralithic contact within 25cm of the soil surface, a slope of less than 25%, and either 0.2% or more organic carbon of Holocene age at a depth of 125 cm below the soil surface with an irregular decrease in organic carbon content from a depth of 25cm to a depth of 125cm (Soil Survey Staff,1998).

These soils are mostly brownish to reddish that formed in recent water-deposited sediments, mainly on deltas and small streams. The

age of the sediments commonly is a few years or decades or a very few hundred years or somewhat more. The Fluvents mainly consist of alluvial sediments came from eroding soil materials or stream banks and contain an appreciable amount of organic carbon that is mainly in the clay fraction. Stratification of the materials is normal, the percentage of organic carbon decreases irregularly with depth.
Torrifluvents is the great group of Fluvents identified in the study area because the soils have a torric moisture regime.

Torrifluvents are Fluvents of arid climate that are not flooded frequently or for long periods. They have a torric moisture regime and most of them are alkaline or calcareous and somewhat salty in some places. The larger areas having favourable topography and commonly cultivated with olives.

One subgroup was recognized within the great group, named Typic Torrifluvents. They do not have a horizon within 1m of the surface that is >15cm thick that either contains as much as 20% durinodes in a nonbrittle matrix or is brittle and has firm consistence. Also, they do not have: (1)cracks within 125cm of the soil surface are 5mm or more wide through a thickness of 30cm or more for some time in most years, and slickensides or wedg-shaped aggregates in a layer 15cm or more thick that has its upper boundary within 125cm of the surface. (2) a linear extensibility of 6cm or more between the soil surface and a depth of 100 cm.

Two soil families were included within the subgroup Typic Torrifluvents, as follows:

***Typic Torrifluvents, sandy, carbonatic, hyperthermic.**

It is represented by soil profile No.2 which is located in the lower part of alluvial deltaic plain of Wadi Wardan. The textural class of the control section is sandy, where these soils have fine sand texture from 25cm to 70cm depth overlying fine sandy loam. The mineralogy is carbonatic, where the calcium carbonate content is more than 40% throughout the profile layers and the soil temperature regime is hyperthermic. These soils are cultivated with olives, using drip irrigation system.

***Typic Torrifluvents, coarse loamy, carbonatic, hyperthermic.**

It is represented by soil profile No.13, which is located in the lower part of alluvial deltaic plain of Wadi Sudr. Textural class of control section is coarse loamy, where these soils have fine sandy loam texture from the soil surface down to 35 cm and very fine sandy loam from 35 to 80 cm overlying gravelly coarse sand. Soil mineralogy is carbonatic, and soil temperature regime is hyperthermic. These soils are prepared for cultivation.

4.5.2.3. Orthents suborder :

Orthents are the Entisols that have more than 35percent rock fragments (by volume) in some subhorizons within a depth of 1m, and do not have fragments of diagnostic horizons. They have an organic carbon content that decreases regularly with increasing depth and reaches a level of 0.2 percent or less within a depth of 1.2m. They are not permanently saturated with water and do not have the characteristics associated with wetness. The soils Orthents are developed on the recent sandy-skeletal alluvium of the upper part of alluvial deltaic plain, the wadi coarse and tributaries.

One great group was defined, named is Torriorthents, and its soils have a torric moisture regime, and have an electrical conductivity of the saturation extract that is 2dS/m or more at 25C° in some part above a depth of 1.25 m.

One subgroup was identified within the great group of Torriorthents, named Typic Torriorthents, its soils do not have a horizon within 1m of the surface, that is more than 15cm thick that either contains 20% or more durinodes in nonbrittle matrix or is brittle and has firm consistence when moist. Also, they do not have a lithic contact within 50 cm of the surface, or cracks within 125 cm of the soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in most years, as well as, do not have slickensides or wedge-shoped aggregates in a layer 15 cm or more thick that has its upper boundary within 125 cm of the soil surface. Typic Torriorthents do not have a linear extensibility of 6.0 cm or more between the soil surface and a depth of 100 cm, and are not saturated with water within 1m of the surface at any time of year in most years. They are dry in all parts of the moisture control section.

Only one soil family was observed within the Typic Torriorthents subgroup, this soil family is:

***Typic Torriorthents, sandy skeletal, carbonatic, hyperthermic.**

It is represented by soil profiles 3,5and 10 which are developed on the upper part of alluvial deltaic plain in Wadi Wardan and Wadi Sudr. The soil textural class is sandy skeletal, where the texture is sand or coarse sand and the gravel content is more than 35% (by volume) in more than half of the control section thickness. The soil

mineralogy is carbonatic as the calcium carbonate content is more than 40%. The soil temperature regime is hyperthermic.

Table (28) summarizes the soil classification of the studied area and Fig.(13) illustrates the physiographic units and included soils in the studied area.

4.6. Land evaluation :

The process of soil survey for the studied area, that aims to assess the potential land suitability for irrigated agriculture, means the land evaluation.

The simple approah proposed by Sys and Verheye (1978), modified by Sys et al. (1991), with the guidence of FAO framework(1976), was used. The structure of this system consists of four categories :

Land suitability orders: reflect kinds of suitability.

Land suitability classes : reflect degrees of suitability within orders.

Land suitability subclasses : reflect kinds of limitation or main kinds of improvement measures required within classes.

Land suitability units : reflect minor differences in the required management within subclasses.

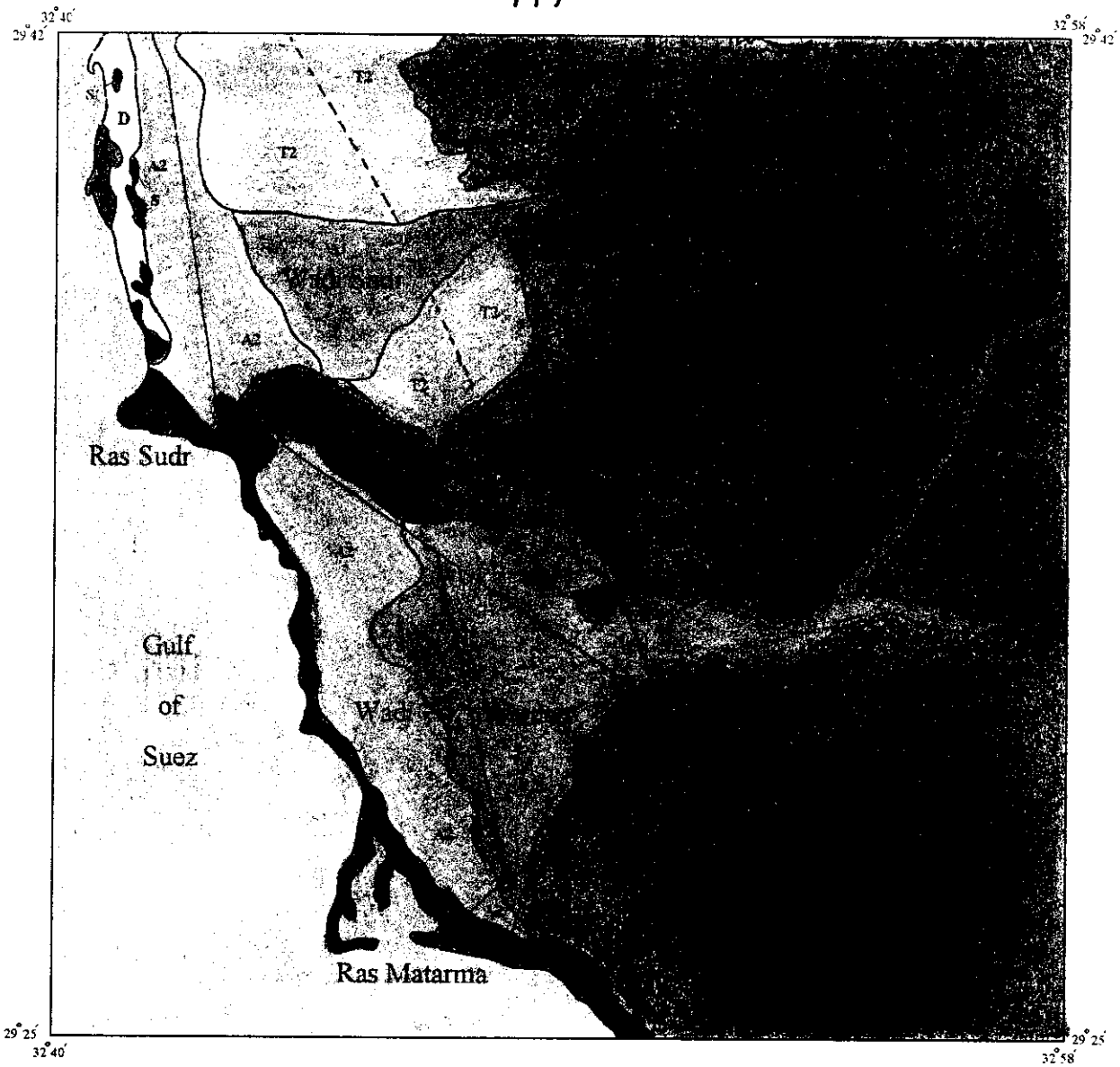
Land suitability orders : indicate whether land is assessed as S(Suitable) or N(Not suitable) for use under consideration. There are two orders :

Order S (Suitable) : land on which sustained use is expected to yield benefits which justify the inputs without unacceptable risk or damage to land resources.

Order N (Not suitable) : land which has qualities that appear to preclude sustained use.

Table (28) : Soil classification categories of the studied area

Order	Suborder	Great group	Subgroup	Soil family	Prof. No.	Physiographic unit
Aridisols	Salids	Haplosalids	Typic Haplosalids	fine loamy, carbonatic,hyperthermic	15	Sabkha
	Gypsids	Haplogypsids	Leptic Haplogypsids	fine loamy, mixed, hyperthermic	8	Playa
				sandy skeletal, carbonatic,hyperthermic	9	Young alluvial terraces
				sandy, carbonatic, hyperthermic	11	
			Typic Haplogypsids	sandy skeletal, carbonatic,hyperthermic	1	Upper deltaic plain
				sandy skeletal, gypsic, hyperthermic	6	Old alluvial terraces
				sandy, carbonatic, hyperthermic	7	
Entisols	Psamments	Torripsamments	Typic Torripsamments	carbonatic, hyperthermic	4	Coastal sand beach
					12	Lower deltaic plain
					14	Oolitic sand dunes
	Fluvents	Torrifluvents	Typic Torrifluvents	sandy, carbonatic, hyperthermic	2	Lower deltaic plain
				coarse loamy, carbonatic, hyperthermic	13	
	Orthents	Torriorthents	Typic Torriorthents	sandy skeletal, carbonatic, hyperthermic	3,5,10	Upper deltaic plain



Map legend

Old alluvial terraces
Typic Haplogypsids, sandy skeletal, gypsic
Typic Haplogypsids, sandy, carbonatic

T2 Young alluvial terraces.
Leptic Haplogypsids, sandy skeletal, carbonatic
Leptic Haplogypsids, sandy, carbonatic

Upper deltaic plain.
Typic Torriothent, sandy skeletal, carbonatic
Typic Haplogypsids, sandy skeletal, carbonatic

Lower deltaic plain.
Typic Torrifluvent, coarse loamy, carbonatic
Typic Torrifluvent, sandy, carbonatic
Typic Torripsamments, carbonatic

Playa
Leptic Haplogypsids, fine loamy, mixed.

Sabkha
Typic Haplosalids, fine loamy, carbonatic

D Oolitic sand dunes
Typic Torripsamments, carbonatic

Coastal sand beach
Typic Torripsamments, carbonatic

Soil temprature regime is hyperthermic.

Miscellaneous land types
Mountains, hills and escarpments.

N
0 2 4 6 8 km.
Scale
Main road
Track
Settlement

Figure (13) Physiographic soil map of the studied area

Land suitability classes : there are three classes within the order S (Suitable) and two classes within the order N(Not suitable).

Class S1 (Highly suitable) : land having no limitations.

Class S2 (Moderately suitable): land having limitations which in aggregate are moderately severe for sustained irrigated agriculture.

Class S3 (Marginally suitable) : land having limitations which in aggregate are severe for sustained irrigated agriculture, and will reduce productivity or benefits, or increase required input.

Class N1 (Currently not suitable) : land having limitations which can not be corrected with existing knowledge at currently acceptable cost, the limitations are so severe as to preclude successful sustained irrigated agriculture.

Class N2 (Permanently not suitable) : land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land for irrigated agriculture.

The characteristics influencing the land suitability with regard to its irrigation capability can be regrouped according to the subclasses of the FAO framework as follows :

-t : topographic limitations.

-w : wetness limitations, mainly based on drainage conditions.

- s : limitations with regard to physical soil conditions, such as:

  s1 : texture including stoniness.

  s2 : soil depth.

  s3 : calcium carbonate status.

  s4 : gypsum status.

-n : salinity and alkalinity limitations.

The evaluation of these land characteristics can be achieved in a relative limitation scale where 5 levels are used. The ratings to be selected for the different limitation levels are given in Table (29), Sys and Verheye(1978)

Table (29) Limitation levels and their ratings.

Symbol	Intensity of limitation	Rating
0	No	95—100
1	Slight	85—95
2	Moderate	60—85
3	Severe	45—60
4	Very severe	<45

The suitability index for irrigation (Ci) is calculated according to the following formula :

Ci = t x w/100 x s1/100 x s2/100 x s3/100 x s4/100 x n/100

Suitability classes can be defined by using the suitability index as follows :

Class S1: Ci > 75

Class S2: Ci 50—75

Class S3: Ci 25—50

Class N1, N2: Ci < 25

Land suitability subclasses are indicated in the symbol using lower case letters applied for limitations. Land suitability units are distinguished by arabic numbers following a hyphen

Two orders S (Suitable) and N (Not suitable), three classes S3 (Marginally suitable), N1 (Currently not suitable), and N2 (Permanently not suitable), and five subclasses were reconized in the study area. Data of land suitability, rating of limitations, and suitability indices of the soils within the different physiographic units are shown in Table (30). The distribution of land suitability is given in Fig. (14).

A detailed description of land suitability is given as follows :

$S3s_1$-1 :

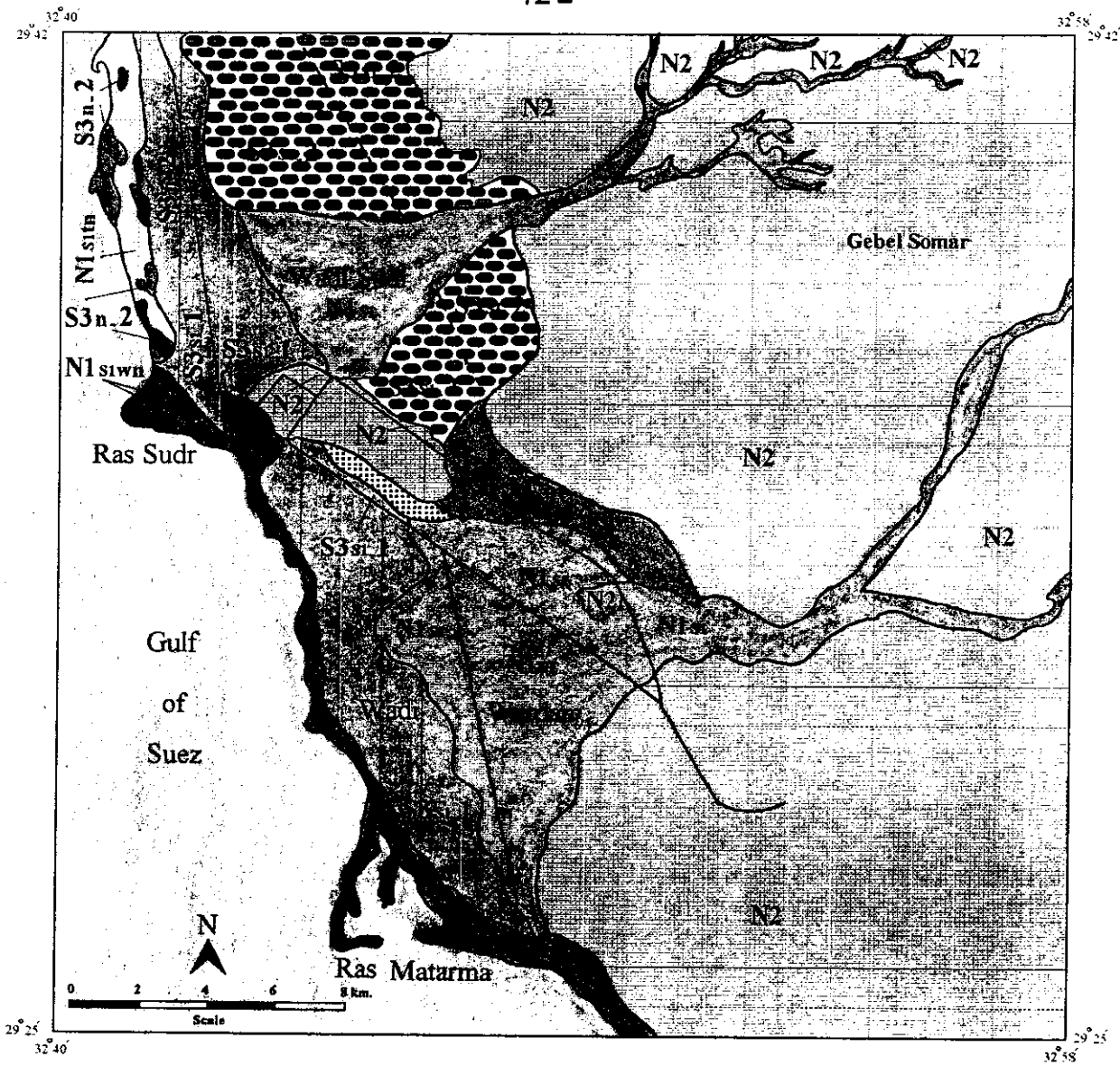
This unit occupies about 15540 Fed., it represents the soils of lower part of alluvial deltaic plain. The suitability index values range from 27.0 to 49.5, indicate marginally suitable class. The soils have moderate to very severe intensity of texture, slight to moderate intensity of calcium carbonate and non to slight intensity of salinity and alkalinty limitations.

$S3s_1$-2 :

This unit occupies about 13310 Fed., it represents the soils of young alluvial terraces. Suitability index values range from 27.4 to 28.7, indicate marginally suitable class. These soils have severe to very severe intensity of texture, a slight intensity of topography and calcium carbonate, non to moderate intensity of gypsum and moderate intensity of salinity and alkalinity limitations.

$S3s_1$-3 :

This unit occupies about 3060 Fed., it represents the soils of old alluvial terraces. Suitability index values range from 27.5 to 29.6 which indicate marginally suitable class. These soils have severe



Land suitability legend

Suitable

Unit symbol	Minor limitation
S3s1_1	s3 and n
S3s1_2	s3, s4 and n
S3s1_3	t, s3, s4 and n
S3n_1	s1 and s4
S3n_2	w and s3

Not suitable

- N1s1
- N1s1tn
- N1s1wn
- N2

Main road
Track
Settlement

S3 : Marginally suitable
N1 : Currently not suitable
N2 : Permanently not suitable

t : Topographic limitation
w : Wetness limitation
s1 : Texture limitation
s3 : Calcium carbonate limitation
s4 : Gypsum limitation
n : Salinity / alkalinity limitation

Figure (14) Land suitability map of the study area

to very severe intensity of texture, a moderate intensity of topography, salinity and alkalinity, non to slight intensity of calcium carbonate, and non to moderate intensity of gypsum limitations.

S3n-1 :

This unit occupies about 540 Fed., it represents the soils of playa (marginally suitable). These soils have moderate intensity of texture, gypsum, salinity and alkalinity limitations.

S3n-2 :

This unit occupies about 700 Fed., it represents the soils of sabkha, which are marginally suitable (suitability index is 43.8). The soils have moderate intensity of wetness, salinity and alkalinity, in addition to slight intensity of topgraphy and calcium carbonate limitations.

$N1s_1$:

This subclass occupies about 24470 Fed., represents the soils of upper alluvial deltaic plain, which have suitability index values range from 9.5 to 19.0, indicating currently not suitable class. Soils of this subclass have very severe intensity of texture, severe intensity of soil depth for profile No.5 only due to the high amounts of coarse fragments in the subsoil and substratum that exceeding 80%, a slight intensity of topography, slight to moderate intensity of calcium carbonate and gypsum, and non to slight intensity of salinity and alkalinity limitations.

$N1s_1$ tn:

This subclass occupies about 1555 Fed., it represents the soils of oolitic sand dunes, which have suitability index value of 13.8, indicating currently not suitable class. Soils of this subclass have very

severe intensity of texture, a moderate intensity of topography, calcium carbonate and salinity and alkalinity and slight intensity of gypsum limitations.

N1s_1 wn:

This subclass occupies about 4970 Fed., it represents the soils of coastal sand beach, which have suitability index values of 9.5, indicating currently not suitable class. Soils of this subclass have very severe intensity of texture, severe intensity of wetness, moderate intensity of calcium carbonate and salinity and alkalinity, and slight intensity of gypsum limitations.

N2:

This suitability class occupies about 100855 Fed., it represents the mountains, hills and escarpments areas. They are rocky lands, highly elevated with steep to very steep slope. They have limitations so severe to preclude any possibilities of successful sustained use of the land for irrigated agriculture.

5. SUMMARY

This study aims to identify the soil characteristics of Wadi Sudr and Wadi Wardan area in the south western part of Sinai for the soil classification and land evaluation purposes. This will be helpful in the planning for agricultural development.

An analysis of landsat TM image covers this area resulted in recognition of the following physiographic units : mountains, hills, and escarpments of sedimentary rocks, old and young alluvial terraces, upper and lower alluvial deltaic plain, playa, sabkhas, oolitic sand dunes and coastal sand beach.

Fifteen soil profiles were morphologically described, and fifty three soil samples were collected for physical and chemical analyses.
Diagnostic horizons such as salic and gypsic horizons were identified for achieving the soil classification according to Soil Taxonomy System.
Land suitability for irrigated agriculture was based on the Sys and Verheye and FAO systems.

The obtained data about the studied phsiographic units could be summarized as follows :-

1- Mountains, hills, and escarpment of sedimentary rocks:

This unit is located at the western part of El Tih plateau, elevation >600m a.s.l. with steep slope. It has rocky surfaces or very shallow soils forming badlands with no potentiality for agriculture. Its suitability class is permanenty not suitable (N2)

2-Old alluvial terraces :

They are about 3060 Fed., have undulating surface, covered with gravel and stones, soil texture is very gravelly to extremely gravelly

coarse sand, transported and deposited by water action, the soils are slightly to strongly saline, with dominant soluble cations of Ca^{+2} and /or Na^{+}, while dominant anions are Cl^{-} and /or $SO_4^{=}$. Soils also, are characterized by low organic matter content (<0.4%), high amount of $CaCO_3$ (13.92-48.29%), and considerable amount of gypsum reaches 28.36 which is enough to form gypsic horizon. CEC values range from 3.25 to 8.98 me/100g soil and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils are classified as:

Typic Haplogypsids, sandy skeletal, gypsic, hyperthermic; and

Typic Haplogypsids, sandy ,carbonatic, hyperthermic.

The studied soils are marginally suitable, with limitations of texture, topography, gypsum, salinity and alkalinity.

3-Young alluvial terraces :

They are about 13310 Fed., have gently undulating surface, covered with gravel and stones, soil texture is gravelly to very gravelly coarse sand, transported and deposited by water action. The soils are moderately to strongly saline, with soluble cations dominated by Na^{+}, while soluble anions dominated by Cl^{-}. Organic matter is <0.4%, $CaCO_3$ range from 33.93 to 50.9% and gypsum reaches 17.2% which is enough to form gypsic horizon. CEC values range from 2.08 to 9.65 me/100g soil and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Leptic Haplogypsids, sandy skeletal, carbonatic, hyperthermic, and

Leptic Haplogypsids, sandy, carbonatic, hyperthermic.

Soils are marginally suitable, with limitations of topography, texture, carbonate, gypsum and salinity and alkalinity.

4-Upper alluvial deltaic plain :

They are about 24470 Fed., have almost flat to gently undulating surface, covered with gravel and stones, desert shrubs and weeds.Soil texture is very gravelly to extremely gravelly coarse sand, soil materials are transported and deposited by water action. Soils commonly are non to slightly saline, and occasionally are strongly saline, O.M.(0.026-0.445%), $CaCO_3$ (26.75-51.33%), gypsum (0.31-0.56%), and occasionally reaches 27.34%. CEC values (1.71-9.44 me/100g soil), and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Typic Torriorthents, sandy skeletal, carbonatic, hyperthermic; and Typic Haplogypsids, sandy skeletal, carbonatic, hyperthermic.

Soils are currently not suitable, with limitations of texture, $CaCO_3$, gypsum, and salinity and alkalinity.

5-Lower alluvial deltaic plain :

They are about 15540 Fed., have almost flat surface, most of the area is cultivated with olives using drip irrigation.

Soil texture is sand and sandy loam, soil materialsare transported and deposited by water and wind action. Soils are non to strongly saline, O.M.(0.053-0.483%), $CaCO_3$ (43.72-54.38%), gypsum (0.37-0.72%). CEC values (2.68-7.96 me/100g soil) and the exchangeable cations dominated by Ca^{+2} and /or Mg^{+2} followed by Na^{+} and K^{+}.

Soils could be classified as :

Typic Torrifluvents, coarse loamy, carbonatic, hyperthermic; and

Typic Torrifluvents, sandy, carbontic, hyperthermic; and

Typic Torripsamments, carbonatic, hyperthermic.

Soils are marginally suitable, with limitations of texture, carbonate, and salinity and alkalinity.

6-Playa :

This unit is about 540 Fed., has almost flat surface, covered with white gravel.

Soil texture is sandy clay loam or sandy loam, soil materialsare transported and deposited by water action. Soils are strongly to extremely saline, O.M.(0.284-0.372%), $CaCO_3$ (13.05-54.38%), and gypsum (1.89-27.11%) with gypsic horizon. CEC values (4.44-13.89 me/100g soil)and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Leptic Haplogypsids, fine loamy, mixed, hyperthermic.

They are marginally suitable, with limitations of texture, gypsum, salinity and alkalinity.

7-Sabkhas :

They are about 700 Fed., have almost flat surface, covered with thin to thick salt crust and pseudosands, common hummocks and many halophytes. Texture is clay loam or silty clay loam, soil materialsare transported and deposited by water and wind actions, soils are extremely saline and salinity is enough to form salic horizon, O.M.(0.29-2.2%), $CaCO_3$ (40-54%) and gypsum (1.0-2.68%). CEC values (10.45-12.78 me/100g soil) and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Typic Haplosalids, fine loamy, carbontic, hyperthermic.

They are marginally suitable with limitations of microrelief, wetness, carbonate, salinity and alkalinity.

8-Oolitic sand dunes :

They are about 1555 Fed., have undulating to rolling surface. Soil texture is sand and soil materials are transported and deposited by both water and wind actions. Soils are strongly saline, EC(22.68-36.28dS/m), O.M.(0.24-0.55%), $CaCO_3$ (94-97%) and gypsum (0.35-0.6%). CEC values (2.41-3.62 me/100g soil) and the exchangeable cations follow the descending order: $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Typic Torripsamments, carbonatic, hyperthermic.

They are currently not suitable, with limitations of topography , texture, carbonate, gypsum, salinity and alkalinity.

9-Coastal sand beach :

This unit is about 4970 Fed., has almost flat surface with thin layer of salt crust, soil texture is sand and soil materialsare transported and deposited by both water and wind actions, soils are moderately to strongly saline (EC 13.77-27.54) O.M.(0.053-0.067%) $CaCO_3$ (54.38-84.83), and gypsum (0.4-0.61%). Soils have saline water table at a depth of 70 cm from the soil surface. CEC values (2.99-5.78 me /100g soil) and the exchangeable cations follow the descending order: $Mg^{+2} > Ca^{+2} > Na^{+} > K^{+}$.

Soils could be classified as :

Typic Torripsamments, carbonatic, hyperthermic.

They are currently not suitable, with limitations of wetness, texture, carbonate, gypsum and salinity and alkalinity.

The obtained results indicated that the studied soils are marginally suitable, currently not suitable or permanently not suitable for

irrigated agriculture, this is due to the presence of limitations with different degrees of intensities. The defined limitations are topography, wetness, texture, soil depth, calcium carbonate, gypsum, salinity and alkalinity.

Improvement of such soils needs beneficial changes including stone clearance, land leveling, subsoil ploughing, construction of perfect system for both irrigation and drainage, reclamation of salinity and alkalinity, application of chemical and organic fertilizers and soil conditioners. The performance of the above mentioned land improvements hopefully will increase the suitability of the studied soils.

6-REFERENCES

Afify, A.A.(1999). " Soil classification of some geomorphological units in south Sinai, using modern techniques". M.Sc. Thesis, Fac. of Agric., Moshtohor, Zagazig Univ.

Alphen, J.G.van, and F.R.Romero, (1971). " Gypsiferous soils". Bull.12, Int. Inst. Land Rec. and Impr., Wageningen, The Netherlands.

Ball, J.(1916). " The topography and geology of west central Sinai". Survey Dept., Cairo.

Beshay, N. F (1991). "Pedological studies on the soils of some wadis in Sinai Peninsula". Ph.D. Thesis, Fac.of Agric., Ain Shams Univ.

Buringh,P.(1960). " Application of aerial photographs in soil surveys". Manual of photographic interpretation, Washington, D.C., 633-666.

Butler, B.E.(1959). " Periodic phenomena in landscapes as a basis for soil studies".C.S.R.I.O. Publ.14-20.

Chorley, R. J., S.A.Schuma and D.E.Sugden (1985). "Geomorphology". Methune, Inc. 733 Third Avenue, New York, U.S.A.

Dames and Moore (1985). " Agricultural and water investigations of Sinai'. Final Report, Volume I –V, Minist.of Dev.&New Comm., Cairo.

El- Ghazawi, M.(1989). "Hydrogeological studies in north east Sinai, Egypt". Ph. D.Thesis, Fac. of Sci., Mansoura Univ.

El-Raey, A.K.(1991). " Structural setting of the area south of Wadi Feiran, east of El-Qaa plain, west central Sinai".M.Sc.Thesis, Fac. of Sci., Ain Shams Univ., Cairo, Egypt.

El-Refai, A.A.(1984). " Geomorphological and hydrogeological studies on El-Qaa plain, Gulf of Suez, Sinai, Egypt". M.Sc. Thesis, Fac. of Sci., Cairo Univ., Egypt.

El-Shamy, I.Z.(1983). " On the hydrology of west central Sinai" Egypt J. Geol., 27: 93-105.

El-Shazly,E.M., M.A. Abdel-Hady., M.A El-Ghawaby; I.A. El-Kassas and M.M. El-Shazly(1974). " Geology of Sinai Peninsula from ERTS-1 Satellite Images". Remote Sensing

Research Project, Academy of Scientific Research and Technology, Cairo, Egypt.

Elwan,A.A,A.A.Harga, H. El-Kadi. And S. El-Demerdash,.(1983). Preliminary studies on the soils of north Sinai peninsula based on aerial photo-interpretation. Egypt.J.Soil Sci.,23: 37—42.

Estes, j. and D. Simonett(1975)."Fundamentals of image interpretation". Manual of remote sensing, Am. Soc.of Photogrametry, 869—1076.

F.A.O.(1976). " A Framework for land evaluation." Soil Bull. 32,Rome.

F.A.O. (1990). "Guidelines for soil profile description". FAO, ISRIC Publication, Rome.

Farag, F.M.(1989). "Chemical and mineralogical characteristics of some Sinai soils". Ph.D. Thesis, Fac.of Agric., Suez Canal Univ.

Folk, R.L., and W.C. Ward,(1957). "A study in the significance of grain size parameters, Brazos River Bar", J.sed. Petr., 27: 3-26.

Geological Survey Authority of Egypt (1994). " Geological map of Sinai, sheet No.3, scale 1:2500". Geological Survey Authority, Cairo, Egypt.

Girgis, W.A. and A.M. Ahmed, (1985). "An Ecological study of wadis of south west Sinai, Egypt". Desert Inst. Bull., A.R.E., 35 : 265 308.

Goosen, D.(1967). " Aerial photointerpretation in soil survey". Soil Bull.6, FAO, Rome.

Hammad,F.A.(1980). " Geomorphological and hydrogeological aspects of Sinai Peninsula, A.R.E". Vol.X, Annals of Geological Survey of Egypt.

Harga, A.A, A.A.Elwan and Y.S.Kassem(1979). " Geomorphology and classification of soils south west of Sinai Peninsula with special reference to Wadi Sudr area based on photo interpretation". Egypt J. Soil Sci., 19: 177-186.

Hume, W.F., (1906). "The topography and geology of Peninsula of Sinai (South Eastern Portion)". Finance Ministry. Survey Department, Cairo, 280pp. Egypt.

Inman, D.L.(1952). " Measures for describing the size distribution of sediments". J. Sed. Petr., 22:125—145.

Jackson, M.L.(1958). "Soil Chemical Analysis". Prentice-Hall, Englewood Cliffs. U.S.A.

Jackson, M.L.(1965). "Soil Chemical Analysis", Advanced Course. Publ. By Author, Madison, Wisconson. U.S.A.

Jackson, M.L.(1969). "Soil Chemical Analysis", Dept. of Soil Sci.,Univ.of Wisconson, Madison, U.S.A.

Jackson, M.L., (1973). "Soil Chemical Analysis". Prentic-Hall. Inc.Engle-Wood, Cliffs.U.S.A.

Jackson, M.L.(1976). "Soil Chemical Analysis". Prentic Hall, India private, LTD, New Delhi.

Kellogg,C.E.(1964). " Soil Survey, classification and correlation new classification system, supplement to 7thApprox". SCS,USDA, Washington,D.C.

Khalil, K.I. (1985). "Pedology of Sinai Peninsula with emphasis on the coastal belt". Ph.D. Thesis, Fac. of Agric., Zagazig Univ., Egypt.

McPherson, J.G., G. Shanmugan and R.J.Moilla (1988). " Fan deltas and braid deltas: varieties of coarse-grained deltas, reply to discussion by L.A.Dunne". Geological Soc. of Amer., Bull.100: 1309—1310.

Moon, F.W. and H. Sadek, (1921). "Topography and geology of Northern Sinai". Petrol. Research Bull.10, Government Press, Cairo, Egypt.

Munsell (1975). " Munsell soil color charts". Baltimore, U.S.A.

Piper, C.S.(1950). " Soil and plant analysis". A monograph from the waite Agric. Res. Inst ., Univ.of Adelaide, S.A., Australia.

Reeuwijk, L.P.Van, (1984). " Introduction to physico-chemical aspect of soil formation". ITC lecturenotes, Sol.6, Enschede, The Netherlands.

Richards, I.A., (1954). "Diagnosis and Improvement of Saline and Alkali Soils". USDA Handbook No.60, U.S.Gov. Printing Office, Washington,D.C.

Sabins, F.F.(1978). " Remote sensing". Principles and interpretation. Freeman& Co., San Fransisco, U.S.A.

Said, R.(1962). "The geology of Egypt" . El-Sevier Publishing Company. Amesterdam, The Netherlands.

Salim, I.M.I.(1995). " Hydro-pedology studies on some soils in Sinai, Egypt". M.Sc. Thesis, Fac. of Agric., Zagazig Univ., Egypt.

Shata, A. (1960). " The geology of Sinai Peninsula". The Enclopedia of Sinai. The Supreme Council of Sci., Government press, Cairo.

Sleen, L.A.Van,(1984). "Physiography and soils" ITC lecturenotes, Sol.20, Enschede, The Netherlands.

Soil Survey Staff, (1975). " Soil Taxonomy". A basic system of soil classification for making and interpreting soil surveys. Agric. Handbook 436,USDA, Washington, D.C.

Soil Survey Staff, (1993). "Soil Survey Manual". U. S. D. A. Handbook No.18, U.S.Government Printing Office, Washington, D.C.

Soil Survey Staff, (1998). "Keys to Soil Taxonomy". 8th edition, SMSS Tech. Mongraph No.19. Blacksburg, Virginia, U.S.A.

Sys, C. (1980). " Land characteristics and quantites and method of rating them". Soil Bull., FAO, Rome.

Sys, C., and W. Verheye (1978). "An attampt to the evaluation of physical land characteristics for irrigation according to the F.A.O. framework for land evaluation". Int. Train. Cent.for Post Grad. Soil Sci., Ghent, Belgium.

Sys, C., E. Van Ranst and J.Debaveye, (1991). "Land Evaluation". Part II, Methods in land evaluation, Int. Train.Cent. for Post Grad., Ghent Univ., Ghent, Belgium.

Thornbury, W.D.(1969). " Principles of geomorphology". John Wiley and Sons, Inc. New York, U.S.A.

Tucker, B.M.(1954). "The determination of exchangeable calcium and magnesium in carbonate soils'. Aust.J.Agric. Res.5.706—715.

USDA, (1954). " Diagnosis and Improvement of Saline and Alkali Soils". USDA, Handbook 60:104

Vink , A.P.A.(1963). " Aerial photographs and the soil sciences". UNESCO, Proc. Toulouse Conf. , 81—141.