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EVALUATION OF LAND RESOURCES FOR AGRENCULTURE DEVELOPMENT IN WADI EL NATROUN AREA, WESTERN DESERT - EGYPT

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ABSTRACT: *The aim of the present work is to evaluate the land resources of Wadi EL-Natroun area, Western Desert, Egypt, for agriculture development. The study area is located in the northeast of the Western Desert between longitudes 30° 15′ and 30° 30′ E and latitudes 30° 15′ and 30° 30′ N with total area about 700 km² (166666 feddan).*

RS and GIS techniques were used for identifying and interpretation the geomorphologic units of the study area. The geomorphologic map of the area was produced using digital image processing of Landsat ETM+, TIN, DEM, geological map and field observation data. Accordingly, three main geomorphologic units with some sub units are recognized. These units are miscellaneous land types (including table land and foot slope units), Wadi El-Natroun depression (including wadi terraces, Wadi plain, overblown sand and salt lakes & sabkhas units) and old alluvial (alluvial plain unit).

Fifteen soil profiles (representing the geomorphologic units) were selected and allocated by the portable Global Positioning System (GPS). Representative 50 soil samples have been collected from the profiles according to the morphological variations. Eight groundwater samples were collected, from water wells of the study area.

The soils are morphologically described in the field. The physical and chemical properties of soil and water samples were determined.

The current suitability of the studied soils was estimated by matching between the present land characteristics and their ratings outlined by Sys and Verhey (1978) and Sys et al (1991).

Suitability indices and classification of the studied soils revealed that there are three suitability classes, i.e., moderately suitable (S2), marginally suitable (S3) and not suitable (N). The soil limiting factors in the study area are texture (s1), salinity and alkalinity (n), depth (s2) and topography (t) with slight to severe and very severe intensity.

Further land improvements are required to correct or reduce the severity of limitations exiting in the studied area, such as: a) leaching of soils salinity and reclamation of soil sodicity, b) continuous application of organic, manure to improve soil physico-chemical properties and fertility status, and c) application of modern irrigation system, i.e. drip and sprinkler. By applying the previous improvement practices, potential suitability of the studied soils could raised to highly suitable (S1) and moderately suitable (S2).

The groundwater suitability for agriculture is classified into three classes according to their salinity and sodium absorption ratio. The northern wells have moderately and marginally suitable. However, the non suitable class of some wells could be due to intrusion of saline water from the adjacent lakes.

Key words: *Land Resources, Land Evaluation, Wadi El-Natroun, RS, GIS, Geomorphologic units.*

INTRODUCTION

The desert area extends to about 94% of the total area of Egypt. The residual area which devoted for agriculture and foundation represents only about 6% of the total area. According to overcrowded annual increasing of the Egyptian population and their fast need for food which decreased as a result of reducing the cultivated lands in Nile valley and Delta due to the transgression by building on the fertile lands. The government of Egypt decided to get out from the narrow valley and searching for other areas for food production. The government looked toward the vast desert especially the Western Desert which represents the great majority of the total area of Egypt for invasion due to its area, suitability, flatness, smoothing and its huge amount of underground water. Wadi EL-Natroun is one of the prominent depressions in the Western Desert that it located at nearly the middle west of Cairo – Alexandria Desert Road. Wadi El Natroun Depression (W.N.D) has an oval shape, with about 50 km in length and its width ranges from 15 to 20 km^2. The total area of the depression that lies below sea level (0 – 23 m b.s.l.) is about 500 km^2 (120,000 fed). Wadi EL-Natroun area also received much attention from the industrial point of view since the third decade of the last century. Some local industries have been constructed in the area. These depend on the occurrence of local resources such as salts from the lakes e.g., Natroun ($Na_2CO_3.10H_2o$ and NaCl) which is used in the soda factory for production of caustic soda and soap and white sand for glass industry.

Location of the study area:

The study area is located in the northeast of the Western Desert between longitudes $30^o\ 15^/$ and $30^o\ 30^/$ E and latitudes $30^o\ 15^/$ and $30^o\ 30^/$ N (Fig. 1) with total area about 700 km^2 (166666 Feddan). There are some newly reclaimed cultivated lands located in the northwest part of the study area and also scattered in the rest of the area as sparse vegetation (Fig 1). They are cultivated with annual crops, vegetables, or fruits. These crops are irrigated mainly from the underground water.

Series of salt – water lakes occupy the different central parts of W.N.D, i.e., (El Fasda and Om El Risha), southern part (El Ruzyna) and the northern part (El Hamra, El Bedia, El Khadra, and El Zaagig). These lakes are separated by windblown barriers of sand, and the lake deposits cover a major portion of the Wadi, which also build up small remnant highest of poorly cemented sandstone and silty clays at the north and the northwest sides of the lakes (Ashmawy 2003).

The climate data representing Wadi EL-Natroun area (Table, 1) are recorded at the climatological station of Wadi EL-Natroun in the period 2000-2010 (Egyptian Meteorological Authority, 2010). The various climate elements at this station indicate that the prevailing conditions are generally characterized by a long dry summer (from April to September) and short rainy warm winter from October to March. Soil temperature regime of the study area could be defined as thermic.

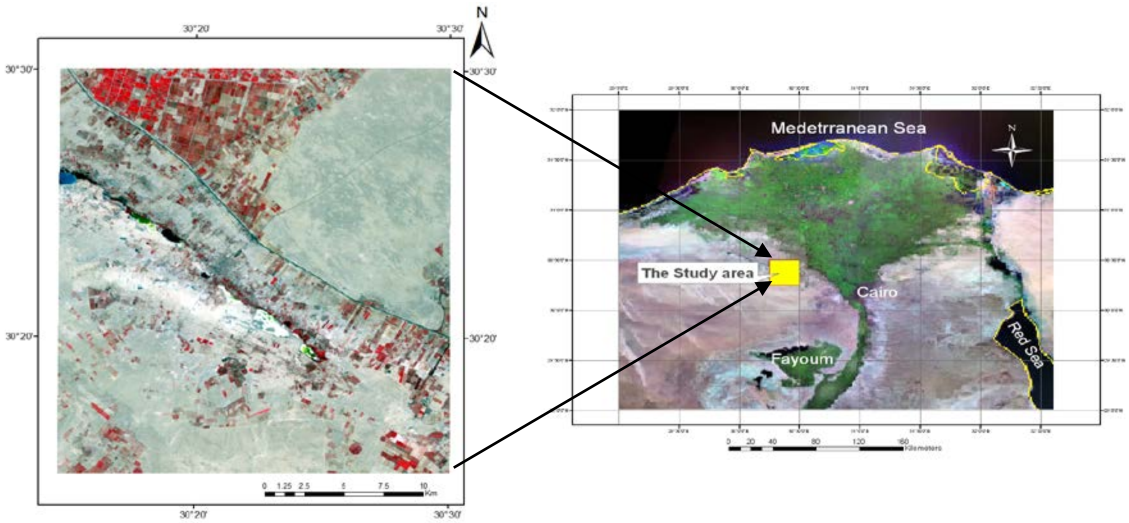

Fig (1) Location of the study area (Wadi El-Natroun, Egypt).

Table (1): Mean monthly climatological data of Wadi El-Natroun area (2000-2010).

Month	Rainfall (mm /day)	Evaporation (mm /day)	Relative Humidity %	Temperature (^oC)		
				Maximum	Minimum	Average
Jan	3.5	5.77	45.89	19.52	7.93	13.73
Feb	2.65	6.92	49.25	21.2	8.73	15.47
Mar	3.04	8.02	48.66	23.8	10.22	17.01
Apr	0.16	11.17	37.74	28.62	13.19	20.91
May	0.3	12.78	48.67	32.11	15.8	23.96
Jun	-	13.4	51.30	34.76	18.77	25.83
Jul	-	12.3	54.27	35.74	20.61	28.16
Aug	-	11.43	57.02	35.49	20.78	28.14
Sep	-	9.02	53.12	29.87	17.22	23.55
Oct	0.08	8.0	54.20	29.82	16.49	23.16
Nov	2.31	6.15	53.09	24.84	12.69	18.76
Dec	3.28	4.68	53.49	20.84	9.43	15.14
Mean	1.27	9.14	50.51	28.05	14.32	21.19
Total	15.24					

Geologic setting:

The surface of Wadi EL-Natroun depression is underlain by both Tertiary and Quaternary sediments with local outcrops of basalt and diorite (Fig. 2). These rocks display different lithofacies (sand, gravel condition). The surface sandstone and clay limestone…etc belonging to different environmental geological structures are rather simple while the subsurface structures are very complicated (Ashmawy, 2003).

A- Tertiary strata:

The Tertiary section was distinct into the Pliocene (235.5 km^2) and Miocene (45.2 km^2) stratigraphic units. The Pliocene and Miocene portion have mostly a direct contribution on Wadi EL-Natroun loose sediments (soil). The following is mainly a brief description of the surface sediments and rock exposures existing in the study area (Ashmawy, 2003).

1-Pliocene:

The Pliocene is dominated by shallow marine and brackish water deposits such deposits one overlain by Nilotic sands and gravel (Pleistocene) and one underlain by a thick sandy section belonging to unconformable to lower Miocene (Moghra Formation).

Upper and Middle Pliocene: (Wadi EL-Natroun Formation):

These sediments are largely restricted to the depression area and are essentially developed into gypseous clays and sands of typical brackish water origin. The portion of Pliocene was distinct into two series, i.e., an upper series (El Mulok) and a lower series (Beni Salama).

Lower Pliocene (El Mekhimin Formation):

The lower Pliocene is exposed in the southern portion of the depression area, namely El Mekhimin, Gabal El Hdid….etc. The exposures are dominated by calcareous conglomerate and sandstone having a thickness of about 5m and this overlying poorly fossiliferous sandstone.

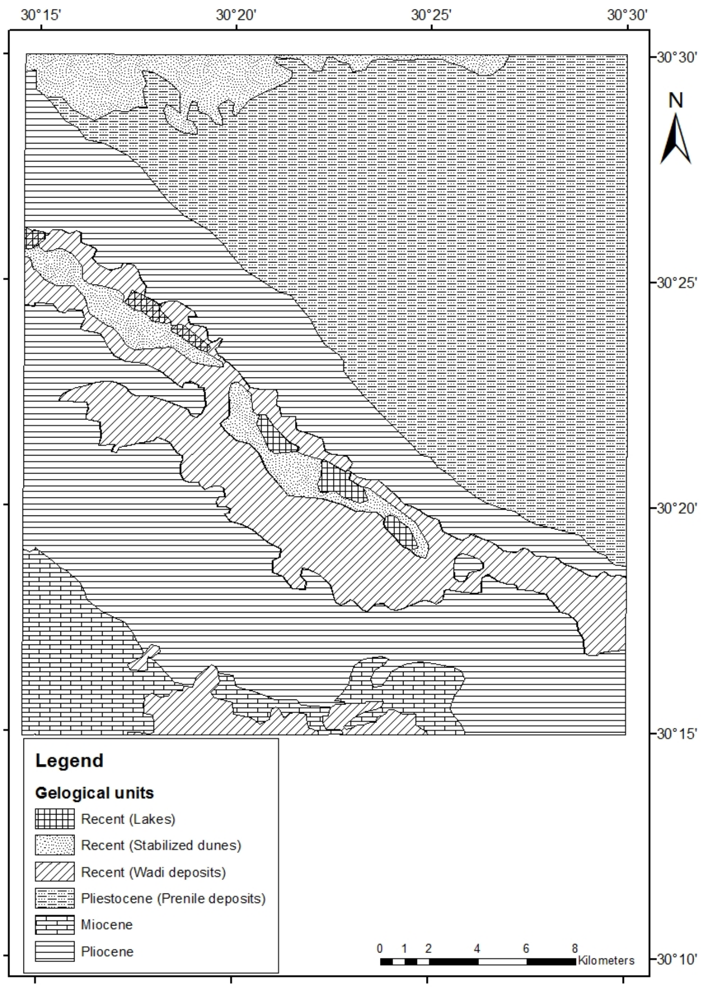

Fig (2): Geological map of the study area (modified after CONCO, 1987).

2- Miocene (thickness 200 m):

The south of Wadi EL-Natroun depression has Miocene rocks. Miocene rocks have a wide distribution and are developed essentially into sand facies. Miocene sediments are well known in most deep wells drilled for water in Wadi EL-Natroun and Wadi El Farigh (Moghra Formation).

B- Quaternary:

Quaternary strata can be categorized into two main types of deposits belonging to the Recent (152.3 km^2) and Pleistocene (265.8 km^2), varying in thickness from 1 to 80 m. It is differentiated into the following deposits:

a) The Nilotic sands and gravels are the lowest part of the Quaternary section and have variable thickness less than 10 m in the depression and more than 300 m in the Delta Basin. Some of the other parts are thin in the depression (Lacustrine deposits), while the rest parts are found in and outside the depression.

b) The pink limestone overlying the Nilotic gravel and sands has been described as a (Crustal Formation). The deposition of this crust bears a relationship to the changes of the climate from the wet condition to the extreme aridity.

The aim of the present work is to evaluate the land and water resources of

Wadi El Natroun area to give an idea about their suitability for agricultural trends.

MATERIALS AND METHODS

Field work:

Field investigations were carried out in the study area using geological map with 1:500.000 scale (CONCO, 1987), topographic map with 1:50,000 scales produced by the Mineral Resources Authority of Egypt (1994) and Satellite data (landsat ETM^+ image with path and row 177 and 39, respectively) acquired in 2004. Different geomorphologic units were identified in the study area.

Fifteen soil profiles were selected representing the identified geomorphological units, and allocated by the Global Positioning System (GPS). Detailed morphological descriptions of the soil profiles were recorded on the base of FAO (1990). Representative 50 soil samples have been collected from the studied soil profiles according to the morphological variations.

Eight groundwater samples were collected representing selected water wells of the study area.

Laboratory analyses:

Soil analyses:

Soil samples were air dried, crushed and sieved through a 2 mm sieve. The fine earth fractions (<2 mm) were used for physical and chemical analyses.

Particle size distribution was determined using the international pipette method (USDA, 2004). Calcium carbonate content was measured using the Collin's Calcimeter method (USDA, 2004). Gypsum was determined by the acetone method (Richards, 1954). Organic matter content was determined according to the method given by Walkley and Black (1947). Soil pH was determined in the soil paste using pH meter and total salinity was expressed as electrical conductivity (ECe dS/m) as well as soluble ions according to (USDA, 2004). Sodium Adsorption ratio (SAR) was calculated according (Richards, 1954).

Land evaluation:

The land capability and suitability evaluation was assessed based on Storie (1964), Sys and Verheye (1978) and Sys *et al* (1991).

Water analyses:

To determine water quality of the study area for agriculture, eight groundwater samples were collected from wells in study area (Fig 5). The samples were analyzed for pH, electrical conductivity (EC), total dissolved salts (TDS), dissolved inorganic constituents, i.e. major cations (Ca^{++}. Mg^{++}, Na^+ and K^+) and major anions (Cl^-, $SO_4^=$ and HCO^-_3) in addition to boron element as described by the American Public Health Association (1989). Also, sodium adsorption ratio (SAR) values were calculated as follows (Richards, 1954):

$SAR = Na\ (meq/L) / \{(Ca + Mg)\ meq\ /L)\}^{0.5}$.

RESULTS AND DISCUSSIONS

I- Geomorphological units:

Wadi El-Natroun depression and its surrounding lands were studied using the remote sensing (RS) and geographic information system (GIS) techniques. Wadi El-Natroun is a morphotectonic depression, having the lowest portion at its center with gradual increase elevation towards the margins of the depression as shown in the distribution of contour lines and spot high points.

Landsat ETM^+ image (Fig 1), geological map (Fig 2), Triangulated Irregular Network (Fig 3), digital elevation model (Fig 4) and data verification by in situ observation were used for delineating the main geomorphologic units (Ismail *et al,* 2009). The study area can be divided into three main landforms and seven geomophological units; namely Miscellaneous land types (Table land and foot slope units), Wadi El-Natroun depression (Wadi terraces, overblown sand, Wadi plain and salt lakes& sabkhas units) and old alluvium (alluvial plain unit) (Fig 5). Each of these landforms shows distinct geomorphological features (Table 2) as follows:

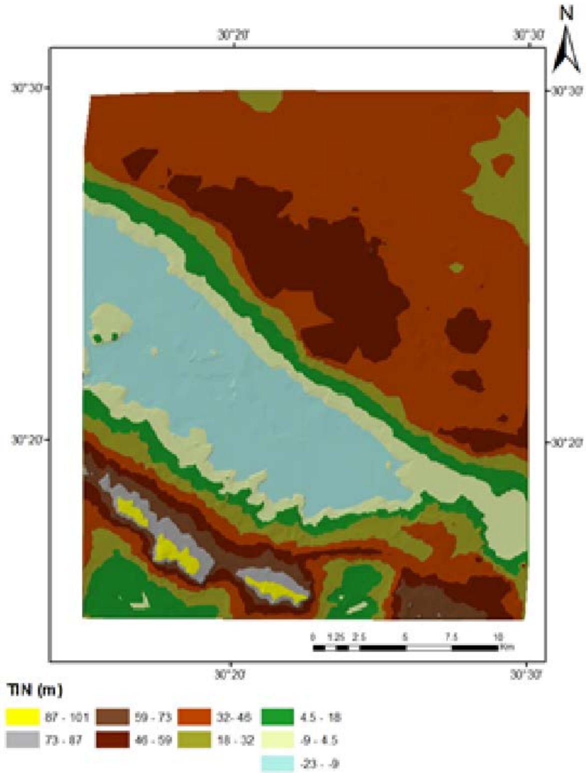

Fig (3): Triangular irregular network (TIN) of the study area

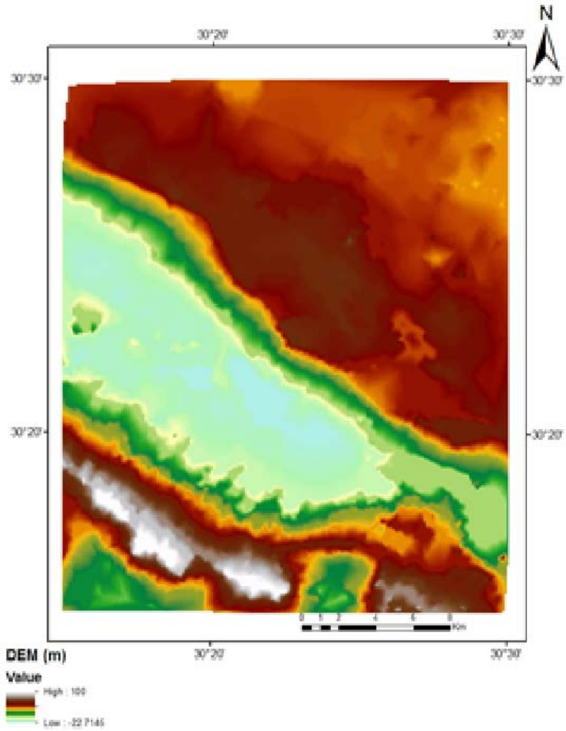

Fig (4): Digital elevation model (DEM) of the study area

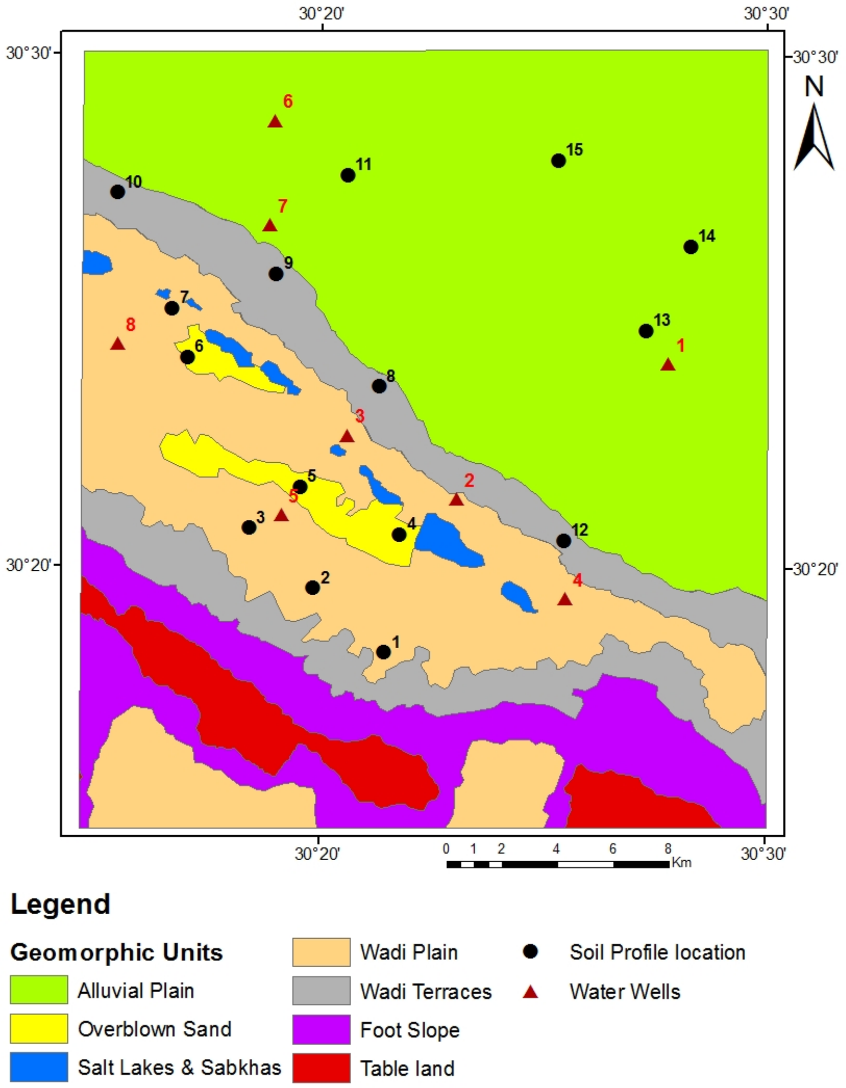

Fig. (5): Geomorphological units and location of soil profiles and water wells in Wadi El-Natroun area.

Table (2): Geomorphological characteristics of the study area

Landform	Geomorphological unit	Geological Age	Relief	Soil profiles	Area	
					Km^2	%
Miscellaneous Land types	Table Land	Pliocene	Very high	-	35.5	5.1
	Foot Slope	Pliocene and Miocene	High	-	75.4	10.8
Wadi El-Natroun Depression	Wadi Terraces	Pliocene	Moderate	8, 9, 10, 12	90.4	12.9
	Overblown sand	Recent	Low	4,5,6	15.4	2.2
	Wadi plain	Recent	Low	1,2,3,7	166.5	23.8
	Salt lakes and Sabkhas	Recent	Very Low	-	6.6	1.0
Old Alluvium	Alluvial Plain	Pleistocene	Moderate	11,13,14,15	308.6	44.2
Total	-	-	-		698.4	100

1- Miscellaneous Land types:

This landform includes two units; namely, the table land and the foot slope. These units could be described as follows:-

a-Table Land unit:

This unit occupies the southern part of the study area that formed by few scarps of low topographic relief. They occur in the form of elongated ridges bordering the two main depressions of Wadi El-Natroun and Wadi El Farigh.

b- Foot Slope unit:

This geomorphologic unit lies around the Table land unit. It is mainly composed of thick sedimentary section belonging mainly to Pliocene and Miocene sequences. This subunit is ranged from about 30 to 55 m ASL elevation with moderate slope toward El-Natroun depression.

2-Wadi El-Natroun Depression:

This landform occupies both of wadi El-Natroun and wadi Al-Farigh depressions. These two depressions resulted from morphotectonic activities. The ground elevations of these two depressions range from -23 to 30 m ASL. The structural depression of Wadi El–Natroun represents a large eroded doubly-plunging anticline structure oriented in a NW-SE direction and bounded by normal faults.

According to the topographic conditions (relief and slope), tectonic setting (fractures, faults and folds), lithology of source area and soils; Wadi El-Natroun depression can be subdivided into the following geomorphologic units:

a- Wadi Terraces:

This unit is distributed around the depression floor of wadi El-Natroun. Its elevation ranges from 0 to 30 m ASL with moderate slope toward the depression floor. The wadi terraces of the study area can be divided into the northern and southern terraces. It is represented by profiles Nos. 8, 9, 10 and 12. The northern terrace cover the portion located between the alluvial plain and wadi El-Natroun depression floor. The southern terrace is mainly undulating surface sloping in the northward direction from El-Mikhimien edge to Wadi El-Natroun depression.

b- Overblown sand:

These deposits were formed by wind action that manifested in the creation of some local cut and fill depression. These Aeolian accumulations consist essentially of well sorted loose, fine to medium quartz size. It is represented by profiles Nos. 4, 5 and 6.

c- Wadi plain:

These deposits were formed by water action of the wadis running from the adjacent high lands (Gabal El-Hadid) to the depression of wadi El-Natroun during flooding. This unit occupies the largest area in wadi El-Natroun depression and is represented by profiles Nos. 1, 2, 3 and 7.

d- Salt Lakes and sabkhas:

Wadi El- Natroun depression is occupied by a series of salt-water lakes, which are the lowest elevation in the depression. It is usually occupied by saline water. These perennial lakes stretch for a distance of about 30 km in the northwestern direction. Most important of them are from northwest to southeast; El-Gaar, Khadra, El-Beida, El-Saad, El-Hamra, Gabboura, El-Rasoneya.

3-Old Alluvium (Alluvial Plain unit):

The alluvial plain unit occupies the area stretched between Wadi El Natroun depression on the southwestern side and Rosetta branch on the northeastern side. It is underlain by dark brown gravel and coarse sand. The surface of this plain is gently undulating and is dissected by shallow runnels directed either to the Nile Delta basin or to Wadi El Natroun depression. The elevation of the ground ranges between 25 m ASL in the southwestern part and 50 m ASL adjacent to the Delta in the eastern part. It is represented by profiles Nos. 11, 13, 14 and 15.

II-Land resources:

1- Soil characteristics:

The soil characteristics of the study area are the basis for soil classification and land use evaluation. These characteristics can be summarized as follows:

a-The study shows that geomorphological unit type is the main factor governing the soil morphology and chemistry. A brief morphological description of the study soil profiles is illustrated in Table (3).

b- The gravel contents are relatively high in alluvial plain unit (5-30 %) followed by wadi terraces unit (0-12 %), while wadi plain unit has low gravel contents (0-4 %); Table (3). Soil textures of the Overblown sand, Wadi Plain and Wadi Terraces units are generally sand, while the Alluvial plain unit is range from sand to clay loam texture (Table 4).

c - The soil chemical analyses can be summarized as follows (Tables 5 and 6):-

- Saturation percentage of soil with water (SP) varies according to soil texture and ranges from 20 to 40 %. The low SP values are due to the coarse texture.
- The average soil reaction (pH) values of wadi plain, wadi terraces and alluvial plain units are fluctuated between slightly and moderately alkaline. However, overblown sand unit is ranged from moderately to strongly alkaline.
- The soil salinity ranges from non saline to very strongly saline. However, the most layers are non- and moderately saline.
- The soluble cations are dominated by Na^+ and followed by Ca^+ and $Mg^{++,}$ while K^+ is the lowest abundant one. On the other hand, Cl^- is the dominant anion followed by $SO_4^=$, while HCO_3- is the least abundant anion. The soluble salts are present mostly as NaCl and $CaSO_4$.
- The soil profiles are mostly having low $CaCO_3$ and gypsum content.
- The organic matter contents are generally low in the study area owing to the prevailing aridity condition.

2- Land suitability for irrigated agricultural:

The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. The land in the survey area has been appraised to estimate its potential of suitability for irrigated agriculture. The ideal approach for land evaluation is based on evaluating the land for a specific land use. Land utilization types (LUT) are the most beneficial use of the land.

From the agricultural point of view, classification of soils for evaluating their capability for irrigation utilization aims at assessing the degree of limitation or suitability for agriculture use on the basis of their permanent properties.

A) Current land suitability:

The current suitability of the studies soils was estimated by matching between the present land characteristics and their ratings according to the system outlined by Sys and Verhey (1978) and Sys *et al* (1991).

Suitability indices and classification of the studied soils representing the studied geomorphic units are shown in Table (7). The results revealed that there are three suitability classes, namely, moderately suitable (S2), marginally suitable (S3) and not suitable (N). The soil limiting factors in the study area are texture (s1), salinity & alkalinity (n), depth (s2) and topography (t) with slight to severe and very severe intensity for soil limitations.

B) Potential Land Suitability:

Further land improvements are required to correct or reduce the severity of limitation exiting in the studied area, such as a) leaching of soils salinity and reclamation of soil sodicity, b) continuous application of organic manure to improve soil properties and fertility status, and c) application of drip and sprinkler irrigation system. By applying these practices, potential suitability of the studied soils could ameliorated to highly suitable (S1), moderately suitable (S2) and marginally suitable (S3).

Table (3): Morphological description of soil profiles in the study area

Geomorphic unit	Profile No.	Depth (cm)	Soil Color (dry)	Structure types	Gravel %	Consistence				Secondary formation		Effervescence	Boundary
						Dry	Moist	Wet					
								ST	PL	K	Y		
Wadi Plain	1	0-20	10YR6/6	MA	1.0	SO	VFR	SST	SPL	-	F	Sl	CW
		20-40	10YR6/6	MA	3.0	SO	VFR	NST	NPL	F	F	Sl	CW
		40-80	7.5YR6/6	MA	4.0	SO	VFR	NST	NPL	F	-	Sl	CW
		80-130	7.5YR7/6	SG	1.0	LO	LO	NST	NPL	F	-	Mo	-
	2	0-30	10YR7/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	GS
		30-80	10YR7/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	GS
		80-130	7.5YR7/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	-
	3	0-15	10YR6/1	SG	1.0	LO	LO	NST	NPL	-	F	Sl	CW
		15-45	10YR7/6	MA	0.0	SHA	FR	ST	PL	F	-	St	CW
		45-55	10YR6/1	MA	0.0	HA	Fi	ST	PL	F	-	St	-
	7	0-50	10YR8/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CW
		50-100	10YR8/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CW
		100-150	10YR7/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	-
Overblown Sand	4	0-20	10YR7/6	MA	0.0	SO	VFR	SST	SPL	-	-	Mo	CW
		20-60	10YR7/6	SG	0.0	LO	LO	NST	NPL	F	-	Mo	CW
		60-75	10YR7/8	SG	0.0	LO	LO	NST	NPL	-	F	Sl	-
	5	0-15	10YR7/4	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CW
		15-50	2.5Y7/4	SG	0.0	SO	SHA	SST	SPL	-	-	Mo	CW
		50-90	5Y6/4	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CW
		90-150	5Y7/4	SG	0.0	SO	SHA	SST	SPL	-	-	Sl	-
	6	0-50	10YR8/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CS
		50-100	10YR7/6	SG	0.0	LO	LO	NST	NPL	-	-	Sl	CW
		100-150	10YR6/6	SG	0.0	LO	LO	NST	NPl	-	-	Sl	-

Table (3): Cont

Geomorphic unit	Profile No.	Depth (cm)	Soil Color (dry)	Structure types	Gravel %	Consistence				Secondary formation		Effervescence	Boundary
						Dry	Moist	Wet					
								ST	PL	K	Y		
Wadi Terraces	8	0-20	10YR6/6	MA	3.0	SO	SHA	SST	SPL	-	-	Mo	CS
		20-60	10YR7/6	MA	1.0	SO	SHA	SST	SPL	F	-	St	CS
		60-110	10YR7/6	SG	1.0	LO	LO	NST	NPL	F	F	St	-
	9	0-15	10YR7/6	MA	5.0	SO	SHA	SST	SPL	-	-	Mo	CW
		15-65	10YR5/6	SG	2.0	LO	LO	NST	NPL	-	-	Sl	CW
		65-100	10YR6/6	SG	2.0	LO	LO	NST	NPL	-	-	Sl	CW
		100-150	10YR5/6	SG	2.0	LO	LO	NST	NPL	-	-	Sl	-
	10	0-40	10YR5/6	MA	1.0	SO	VFR	SST	SPL	-	-	Mo	CW
		40-90	10YR6/4	SG	6.0	LO	LO	NST	NPL	F	-	Mo	CW
		90-130	10YR6/4	SG	12.0	LO	LO	NST	NPL	F	-	Mo	-
	12	0-10	10YR6/6	MA	2.0	SO	VFR	SST	SPL	-	F	Sl	CS
		10-25	10YR5/4	MA	0.0	SHA	FR	ST	PL	-	F	Sl	CS
		25-55	10YR5/2	MA	0.0	SHA	FR	ST	PL	-	-	Sl	-
Alluvial Plain	11	0-25	10YR 6/6	MA	5.0	SHA	FR	SST	SPL	-	-	Mo	CW
		25-50	10YR 7/6	MA	12.0	SO	VFR	NST	NPL	F	-	Mo	CW
		50-100	10YR 8/6	MA	0.0	SO	VFR	NST	NPL	-	-	Sl	CW
		100-150	10YR 6/6	MA	12.0	SO	VFR	NST	NPL	-	-	Sl	-
	13	0-20	10YR 6/4	MA	20.0	SO	VFR	SST	SPL	-	-	Mo	CW
		20-65	10YR 5/6	MA	5.0	SO	VFR	ST	PL	F	-	Mo	CW
		65-150	10YR 5/6	MA	5.0	HA	Fi	ST	ST	F	-	Mo	-
	14	0-20	10YR 5/6	MA	5.0	SO	SHA	SST	SPL	F	-	St	CW
		20-60	7.5YR 6/6	MA	3.0	SO	SHA	SST	SPL	F	-	St	CW
		60-150		SG	3.0	SO	SHA	NST	NPL	-	-	Sl	-
	15	0-10	10YR6/4	MA	5.0	SO	SHA	SST	SPL	-	-	Mo	CW
		10-40	10YR7/6	SG	30.0	SO	SHA	SST	SPL	F	F	Mo	CW
		40-90	10YR7/6	SG	15.0	LO	LO	NST	NPL	-	F	Sl	CW
		90-150	10YR7/6	SG	10.0	LO	LO	NST	NPL	-	-	Sl	-

Structure Types
MA : Massive
SG : Single grains

Consistence
LO : Loose
SO :Soft
SHA : Slightly hard
VFR :Very Friable
FR :Friable
HA : Hard
Fi :Firm
NST : Non Sticky
SST : Slight Sticky
NPL :Non Plastic
SPL :Slightly plastic
ST : Sticky
PL : Plastic

Secondary Formation
K : Accumulation of lime
Y : Accumulation of Gypsum
F : Few (2-5%)

Effervescence
St : Strongly calcareous
Mo :Moderate calcareous
Sl : Slightly calcareous

Boundary
C :Clear
S : Smooth
W : Wavy

Table (4): Particle size distribution of the studied soil profiles.

Geomorphic Unit	Profile No.	Depth (cm)	Coarse sand %	Fine sand %	Silt %	Clay %	Texture Class
Wadi Plain	1	0-20	62.7	24.85	5.83	6.62	Sand
		20-40	73.2	18.27	3.73	4.8	Sand
		40-80	87.2	5.25	4.68	2.87	Sand
		80-130	87.08	3.78	3.12	6.02	Sand
	2	0-30	94.34	1.04	2.07	2.55	Sand
		30-80	94.36	0.56	1.72	3.36	Sand
		80-130	95.76	1.17	2.16	0.91	Sand
	3	0-15	93.16	1.8	1.87	3.17	Sand
		15-45	36.1	6.37	18.89	38.64	clay Loam
		45-55	6.04	36.88	21.18	35.9	clay Loam
	7	0-50	76.20	18.25	3.52	2.03	Sand
		50-100	64.60	28.14	5.17	2.09	Sand
		100-150	66.20	26.89	4.72	2.19	Sand
Overblown Sand	4	0-20	80.02	10.02	6.12	3.84	Sand
		20-60	91.6	4.26	3.36	0.78	Sand
		60-75	91.90	4.43	1.97	1.7	Sand
	5	0-15	83.52	10.19	1.69	4.6	Sand
		15-50	90.48	3.11	2.24	4.17	Sand
		50-90	75.34	17.77	1.88	5.07	Sand
		90-150	93.94	4.06	0.5	1.5	Sand
	6	0-50	77.40	17.93	3.65	1.02	Sand
		50-100	77.20	16.85	4.83	1.12	Sand
		100-150	88.64	6.76	1.1	3.5	Sand
Wadi Terraces	8	0-20	74.74	21.01	1.51	2.74	Sand
		20-60	47.56	44.64	5.4	2.4	Sand
		60-110	60.54	32.24	5.1	2.12	Sand
	9	0-15	82.64	12.18	1.43	3.75	Sand
		15-65	81.90	5.22	8.33	4.5	Sand
		65-100	85.82	12.9	0.68	0.6	Sand
		100-150	90.48	5.49	3.13	0.9	Sand
	10	0-40	79.64	16.19	1.2	4.97	Sand
		40-90	88.20	6.27	1.46	4.07	Sand
		90-130	86.12	13.11	0.27	05	Sand
	12	0-10	50.36	43.42	2.12	5.01	Sand
		10-25	25.12	51.06	4.87	18.95	Sandy Loam
		25-55	52.08	20.71	7.41	19.08	Sandy Loam
Alluvial Plain	11	0-25	72.60	2.27	11.13	13.7	Sandy Loam
		25-50	88.5	6.53	4.27	0.78	Sand
		50-100	79.42	16.68	1.14	2.76	Sand
		100-150	88.24	10.92	0.46	0.38	Sand
	13	0-20	70.22	7.58	10.67	11.53	Sandy Loam
		20-65	70.22	5.32	8.3	16.16	Sandy Loam
		65-150	75.90	3.72	3.73	16.65	Sandy Loam
	14	0-20	60.12	21.55	4.25	14.08	Sandy Loam
		20-60	80.42	3.05	4.85	11.68	Loamy Sand
		60-150	86.32	9.62	2.89	1.17	Sand
	15	0-10	44.32	37.58	5.62	12.48	Loamy sand
		10-40	88.10	2.20	0.95	8.75	Sand
		40-90	90.04	7.04	1.96	0.96	Sand
		90-150	87.02	6.72	1.46	4.80	Sand

Table 5

Table 5

Table (6): $CaCO_3$, organic matter and gypsum contents of the studied soil profiles.

Geomorphic Unit	Profile No.	Depth (cm)	$CaCO_3$ %	Organic Matter %	Gypsum %
Wadi Plain	1	0-20	3.2	0.51	6.27
		20-40	2.1	0.16	4.21
		40-80	1.6	0.1	2.07
		80-130	4.9	0.41	2.06
	2	0-30	1.6	0.34	0.97
		30-80	1.2	0.37	1.99
		80-130	1.6	0.34	1.46
	3	0-15	1.8	0.44	4.18
		15-45	11.5	0.39	0.28
		45-55	7.9	0.64	0.25
	7	0-50	1.3	0.40	0.19
		50-100	1.8	0.24	0.17
		100-150	3.0	0.26	0.23
Overblown Sand	4	0-20	3.9	0.36	0.30
		20-60	4.1	0.41	0.18
		60-75	2.1	0.28	2.77
	5	0-15	2.4	0.67	1.01
		15-50	6.5	0.41	0.91
		50-90	2.5	0.43	0.78
		90-150	2.5	0.46	0.00
	6	0-50	1.7	0.31	0.00
		50-100	2.2	0.26	0.01
		100-150	2.3	0.26	0.23
Wadi Terraces	8	0-20	5.3	0.7	0.20
		20-60	10.3	0.0	1.02
		60-110	11.1	0.33	4.16
	9	0-15	2.6	0.03	1.87
		15-65	2.9	0.30	0.77
		65-100	1.8	0.26	1.08
		100-150	3.0		0.52
	10	0-40	7.4	0.28	0.93
		40-90	6.5	0.26	3.74
		90-130	5.3	0.7	3.55
	12	0-10	3.3	0.49	4.85
		10-25	1.2	0.34	2.46
		25-55	2.1	0.41	1.07
Alluvial Plain	11	0-25	6.03	0.51	0.47
		25-50	4.3	0.42	0.55
		50-100	1.7	0.25	0.51
		100-150	3.01	0.27	0.55
	13	0-20	4.7	0.01	0.10
		20-65	4.8	0.11	0.00
		65-150	5.6	0.13	0.8
	14	1-20	7.8	0.14	0.25
		20-60	6.0	0.0	0.10
		60-150	4.7	0.0	0.79
	15	0-10	5.2	0.50	0.11
		10-40	6.2	0.36	3.35
		40-90	2.2	0.30	3.17
		90-150	2.6	0.03	0.75

Table (7): *Degree of soil limitations and suitability classes of the studied soil profiles.

Geomorphic unit	Profile No.	t		w		Soil Physical characteristics (s)					n		Ci		Suitability classes	
						s1		s2	s3	s4						
		c	p	c	p	c	p				c	p	c	p	c	p
Wadi Plain	1	95	100	100	100	٤٠	60	100	١٠٠	100	٤٥	100	17.1	60	N1sn	S2s
	2	95	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	١٠٠	١٠٠	38.0	60	S3s	S2s
	3	95	١٠٠	١٠٠	١٠٠	٨٥	85	75	100	١٠٠	٨٠	١٠٠	38.8	63.8	S3sn	S2s
	7	95	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	٩٦	١٠٠	36.5	60	S3s	S2s
Overblown Sand	٤	95	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	٤٥	١٠٠	17.1	60	N1sn	S2s
	٥	95	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	٤٥	١٠٠	17.1	60	N1sn	S2s
	٦	95	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	٨٠	١٠٠	30.4	60	S3sn	S2s
Wadi Terraces	8	90	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	100	١٠٠	١٠٠	١٠٠	32.4	60	S3s	S2s
	٩	90	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	٩٠	١٠٠	32.4	60	S3s	S2s
	١٠	90	١٠٠	١٠٠	١٠٠	٤٠	60	١٠٠	١٠٠	١٠٠	١٠٠	١٠٠	36.0	60	S3s	S2s
	١٢	90	١٠٠	١٠٠	١٠٠	٧٥	80	٧٥	١٠٠	١٠٠	٩٦	١٠٠	48.6	60	S2 s	S2s
Alluvial Plain	١١	95	١٠٠	١٠٠	١٠٠	٥٥	65	100	١٠٠	١٠٠	١٠٠	١٠٠	52.3	65	S2s	S2s
	١٣	95	١٠٠	١٠٠	١٠٠	٧٥	80	100	١٠٠	١٠٠	٩٠	١٠٠	64.1	80	S2s	S1
	١٤	95	١٠٠	١٠٠	١٠٠	٥٥	65	١٠٠	١٠٠	١٠٠	١٠٠	١٠٠	52.3	65	S2s	S2s
	١٥	95	100	100	100	٥٥	65	١٠٠	١٠٠	100	٧٥	100	39.2	65	S3sn	S2s

t = Topography w= wetness s1= texture s2 = soil depth s3= $CaCO_3$ s4= $CaSO_4.2H_2O$ n= salinity &alkalinity c= current p=potential Ci=Capability index

* no (95-100), slight (85-95), moderate (60-85) severe (45-60), very severe (<45).

III-Water resources:

1-Surface water:

To the north and east of the study area, there is a fresh surface water coming from the River Nile which includes El-Rayah El-Beheri, El-Rayah El -Nasseri, El- Nubaria canal and El-Nasr canal. Also, there are eight principle salt lakes in Wadi El- Natroun, which arranged from southeast to northwest as follows: El-Fasda, Um Risha, Gabboura and El- Hamra, Zagum, El-Beida, Khadra and El-Gaar (Abd El Salam, 1997). The surface fresh water of the irrigation system find its way downwards to percolate and infiltrate through these predominant structures and porous stratigraphic column to provide the subsurface aquifers with the Nile fresh water.

2-Groundwater:

In the main depression of Wadi El Natroun, the Aeolian and alluvium deposits acts as a reservoir in which the level of the groundwater ranges between 1 and 3 m from the ground surface. Also, in the main depression, the lakes act as a discharge area for the groundwater reservoirs in the study area. In Alluvial plain and Wadi Terrace units, the groundwater follows the surface relief and the depth to groundwater decrease towards the depression floor. Furthermore, Gabal El-Hadid acts as watershed area for the different reservoirs of Wadi El Natroun since all the drainage lines are directed towards its depression.

The different reservoirs in the study area are directly recharged from the surface water system (El-Nasr canal, El-Nubaria canal, El-Rayah El- Behery and El-Rayah El-Nasery) and from the Quaternary reservoir of the Nile Delta as well. Hence, they are hydraulically connected (Shata *et al.,* 1962 and Abdel Baki, 1983). Accordingly these reservoirs are located as one hydraulic system. These could be differentiated into the following water bearing reservoir (Abd El Salam, 1997):

1- The Recent reservoir (average thickness 10 m)
2-The Pleistocene reservoir (Average thickness 100 m)
3- The Pliocene reservoir (Average thickness 50 m)
4-Miocene reservoir El-Moghra aquifer (Average thickness 200 m)

A) Chemical characteristics of groundwater:

pH value:

The pH of the groundwater samples ranged from 7.5 (Well No. 3) to 9.1 (Well No. 8) with an average of 7.9 (Table 8).

Electrical conductivity (EC):

The EC of studied groundwater samples ranged from 0.5 dS/m (Well No.2) to 2.77 dS/m (Well No.8) with an average of 1.63 dS/m. Consequently, this water is suitable for irrigation (Table 8).

Total dissolved Salts (T.D.S):

The salinity of the groundwater samples ranged from 320 mgL^- (Well No. 2) to 1741 mgL^- (Well No. 8) with an average of 800 mgL^- (Table 8).

Major Cations:

Sodium content:

The sodium content of the deep groundwater ranged from 130 mgL^- (Well No.2) to 1370 mgL^- (Well No.8) with an average of 493.1 mgL^-. This may be due to excessive pumping and salt water intrusion from deep reservoirs (Table 8).

Calcium content:

Calcium content of the groundwater samples ranged between 55 mgL^- (Well No.7) and 384 mgL^- (Well No.3) with an average of 131.5 mgL^- (Table 8).

Magnesium content:

In The magnesium content of the groundwater samples ranged from 70 mgL^- (Well No. 7) to 416 mgL^- (Well No. 3) with an average of 168.9 mgL^- (Table 8).

Potassium content:

The potassium content of groundwater samples ranged from 6.0 mgL^- (Well No.2) to 64.0 mgL^- (Well No.3) with an average of ١٨.٧ mgL^- (Table 8).

E- Major Anions:

Chloride content:

The chloride content of the groundwater samples of the study area ranged from ١٥٥ mgL^- (Well No.٢) to 1400 mgL^- (Well No.8) with an average of ٤٩٨.٢ mgL^- (Table 8).

Carbonates and bicarbonate contents:

The bicarbonate content of the deep groundwater ranged between ٣٢ mgL^- in Well No. ٤ and ٥١ mgL^- in sample No.8 (Table 8).

Sulphate content:

The sulphate content of the groundwater ranged from ١٢٥ mgL^- (Well No.7) to ٧٧٠ mgL^- (Well No.٣) with average of 431 mgL^-.

Boron content:

Boron is important element which determined the toxicity of groundwater. Boron concentration less than 0.5 mgL^- is very good for irrigation, 0.5-2.0 mgL^- is good water for irrigation and more than 2 mgL^- is toxic water (Ayers and Westcot, 1985). In the study area, it is very good water in wells Nos. 1, 2 and 6; good water in wells Nos. 4, 5 and 7; and toxic water in wells Nos. 3 and 8 as shown in Table (8). Boron can release into water and soil water through weathering processes and to a much smaller extent, through anthropogenic discharge such as sewage outfalls (WHO, 1998).

Table 8

B) Suitability of water for irrigation:

The principles of water characteristics that determine its quality for irrigation are:

- The total concentration of soluble salts.
- Relative proportion of sodium to other cations.
- The bicarbonate concentration as related to the concentration of calcium plus magnesium.
- Concentration of boron or other toxic elements

a- Classification according to salinity content:

The classification of the studied water samples quality according to their soluble salt contents (Table 9) was performed according to the U.S. Salinity Laboratory system modified by El - Ghandour *et. al.* (1983). This classification could be summarized in the following:

1-Low saline water contains soluble salts less than 160 mgL^{-}. Its EC ranged between 0 and 0.25 dS/m.

2-Medium saline water contains 160-480 mgL^{-}. It's EC ranged between 0.25 and 0.75 dS/m

3-High saline water contains 480-1448 mgL^{-} .Its EC ranged between 0.75 to 2.25 dS/m

4-Very high saline water contains 1440 - 3200 mgL^{-} . Its EC ranged between 2.25 and 5.0 dS/m.

5-Excessive saline water contains more than 3200 mgL^{-}and its EC more than 5.0 dS/m.

The results indicated that the groundwater samples Nos. 1, 2 and 6 fall under the second category. Water of this category has a good quality for irrigation of all crops without harmful effect. Samples Nos. 4, 5 and 7 are fall under the third category. Samples Nos. 3 and 8 fall under the fourth category. This category needs special management. Salts tolerant plants must be chosen.

b- Classification according to EC and SAR:

The US salinity laboratory (Richards, 1954) assumed the level of sodium absorption ratio (SAR) in addition to the EC for the assessment of irrigated water quality.

Accordingly, the studied groundwater suitability for agriculture was classified into three classes (Table 9). The northern wells (Nos.1 to 4) have moderately and marginally suitable classes. However, the wells Nos. 5 to 8 have non suitable class due to intrusion of saline water from the lakes adjacent to these wells in the study area.

Table (9): Quality classification for agriculture of some water wells in the study area.

Well No.	Well name	EC dS/m	Suitability according to EC	SAR	Suitability According to EC and SAR	Suitability class
1	Ground water station	0.53	Medium saline	١٢.٧	C2-S1	Moderate
2	El – Sharway Farm	0.5	Medium saline	12.9	C2-S2	Moderate
3	El-Ahram Farm	2.7	Very high saline	42.5	C4-S4	Non
4	Water Distribution Station	0.89	High saline	٣١.٤	C3-S4	Marginal
5	EL Rowad El - Arab	1.23	High saline	٤٥.٦	C3-S4	Marginal
6	El - Bostan	0.56	Medium saline	١٣.٢	C2-S1	Moderate
7	EL - Lams	0.9	High saline	٦٠.٧	C3-S4	Marginal
8	EL- Gehaz EL-Markazy Well	2.77	Very high saline	١٠٠.٧	C4-S4	Non

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تقييم الموارد الأرضية للتنمية الزراعية فى منطقة وادى النطرون بالصحراء الغربية, مصر

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الملخص العربى

تهدف الدراسة الى تقييم الموارد الأرضية والمائية لمنطقة وادى النطرون وذلك بالتعرف على الوحدات الجيومورفولوجية الرئيسية بأستخدام تقنيات الإستشعار من بعد ونظم المعلومات الجغرافية. وكذلك بدراسة الخصائص الطبيعية والكيميائية للتربة والخصائص الهيدرولوجية (دراسة المياه السطحية والجوفية) لهذه الوحدات الجيومورفولوجية بغرض تقييم مدى ملائمة كل من التربة والمياه للزراعة.

وجد أن الوحدات الجيومورفولوجية الرئيسية فى منطقة الدراسة هى: أراضى المرتفعات Table land ، المنحدرات الجبلية Foot slope ، شرفات الوادى Wadi terraces ، رواسب الرمل الهوائية Overblown sand ، رواسب السهول الوديانية Wadi Plain، البحيرات المالحة والسبخات Salt lakes & Sabkhas وترسيبات السهول المائيه Alluvial Plain.

الدراسات الحقلية للوحدات الجيومورفولوجية شملت الوصف المورفولوجى وجمع عدد ١٥ قطاعا أرضيا تمثل وحدات التربة وذلك بإستخدام جهاز تحديد الموقع GPS. وتم جمع عدد ٥٠ عينة تمثل طبقات قطاعات التربة المختلفة. كذلك تم فحص وجمع عدد ٨ عينات مياه من أبار المياة الجوفية فى منطقة الدراسة.

الدراسات المعملية شملت دراسة خواص عينات التربة الطبيعية والكيميائية وكذلك خواص عينات المياه الجوفية الكيميائية بغرض تقييم التربة والمياه فى منطقة الدراسة للأغراض الزراعية.

وطبقا لنظام تقييم الأراضي المتبع بواسطة Sys and Verheye (1978)، Sys *et.al.* (1991) تم تقييم أراضي الوحدات الجيورموفولوجية بغرض تحديد مدى ملائمتها للزراعات المروية بصورتها الحالية أو بعد معالجة محددات التربة للحصول على أعلى عائد وتشير نتائج أدلة الملائمة على انتمائها الي ثلاث رتب هى أراضي متوسطة الصلاحية (S2) وهامشية الصلاحية (S3) وغير صالحة للزراعة بصورتها الحالية (N1) وكانت محددات صلاحية التربة فى هذه الرتب هى القوام ، الملوحة والقلوية وعمق قطاع التربة الفعالة وبدرجات شده مختلفة (متوسطة ، شديدة ،شديدة جدا), وبرفع القدرة الإنتاجية لهذه الأراضي عن طريق عمليات تحسين التربة تصبح درجات الصلاحية الكامنة للأراضي هي عالية الصلاحية (S1) متوسطة الصلاحية (S2) و هامشية الصلاحية (S3)

وبدراسة الخواص الكيميائية للمياه الجوفية فى المنطقة خاصة الملوحة EC ونسبة امتصاص الصوديوم SAR. وجد أن هناك آبار متوسطة الصلاحية وآبار حدية الصلاحية وآخرى عديمة الصلاحية للزراعة.

Table (5): Chemical analysis of the studied soils.

Geomorphic Unit	Profile No	Depth (cm)	SP (%)	pH	EC dS/m	T.D.S %	Cations (meq/L)				Anions (meq/L)			SAR
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	$SO4^{--}$	
Wadi Plain	1	0-20	20	7.7	76.48	1.47	195.7	89.6	1038.0	20.0	1020.0	5.0	318.4	87.2
		20-40	21	8.6	9.84	0.17	58.2	51.6	71.2	1.5	130.0	5.0	47.5	9.6
		40-80	20	8.6	5.37	0.12	24.5	10.0	34.6	0.7	50.0	6.0	14.2	8.9
		80-130	20	8.5	7.04	0.09	31.0	22.9	46.0	0.8	60.0	9.0	32.2	8.8
	2	0-30	25	8.5	2.82	0.04	11.5	6.7	10.8	0.7	20.0	5.0	4.8	3.3
		30-80	23	8.6	4.69	0.06	22.5	11.7	32.7	0.9	45.0	3.1	19.9	6.1
		80-130	27	8.5	2.95	0.05	7.6	6.9	15.9	0.7	18.0	3.0	10.0	5.9
	3	0-15	23	8.0	10.9	0.16	68.6	52.8	77.2	1.5	120.0	4.0	34.2	9.9
		15-45	38	8.7	9.72	0.18	27.6	18.1	86.2	1.2	100.0	4.0	29.3	11.5
		45-55	40	8.8	1.67	0.05	2.9	2.5	11.0	0.3	12.0	3.0	1.7	6.7
	7	0-50	25	8.2	1.35	0.02	1.8	1.1	10.9	0.7	9.0	4.0	1.5	9.0
		50-100	27	8.0	1.41	0.02	1.8	1.5	10.0	0.5	9.0	4.0	1.1	7.6
		100-150	26	8.0	1.45	0.02	1.8	1.2	11.1	0.4	10.0	3.5	1.0	9.0
Overblown Sand	4	0-20	25	9.5	138.33	2.2	154.9	152.7	5437.0	5.0	5540.0	4.5	155.9	438.0
		20-60	22	9.4	3.51	0.04	3.9	2.6	28.0	0.6	28.0	4.0	3.2	15.5
		60-75	25	8.4	5.95	0.09	3.9	4.3	51.3	0.8	49.0	5.0	6.3	25.3
	5	0-15	20	8.0	61.77	1.02	58.8	93.6	1017.0	16.5	1340.0	3.0	153.1	116.5
		15-50	21	8.2	4.73	0.08	5.7	3.3	37.3	1.0	38.0	3.0	6.4	17.5
		50-90	23	7.8	2.69	0. 56	3.3	2.5	20.7	0.4	22.0	2.0	2.9	12.1
		90-150	23	7.7	28.19	0.59	40.8	38.5	508.8	3.1	52.0	3.0	68.3	6.2
	6	0-50	24	8.3	25.02	0.34	88.2	187.9	230.0	1.5	420.0	4.5	83.2	19.0
		50-100	23	8.5	1.82	0.29	2.8	2.0	11.9	1.48	10.0	4.6	3.6	7.6
		100-150	23	8.1	2.92	0. 29	5.5	4.2	17.7	1.78	22.0	3.0	4.2	8.0

Table (5): Cont

Geomorphic Unit	Profile No	Depth (cm)	SP (%)	pH	EC dS/m (at 25°c)	T.D.S %	Cations (meq/L)				Anions (meq/L)			SAR
							Ca^{++}	Mg^{++}	Na^+ Na^+	K^+	Cl^-	HCO_3^-	SO_4^{--}	
Wadi Terraces	8	0-20	22	7.1	3.89	0.12	17.7	5.86	15.0	0.3	30.0	4.0	4.92	4.37
		20-60	20	7.6	0.87	0. 16	2.8	1.03	4.6	0.3	40.0	3.0	1.71	3.58
		60-110	23	7.3	2.02	0.09	5.5	4.71	9.56	0.4	5.2	3.0	12.0	4.23
	9	0-15	22	7.4	17.52	0.24	28.4	73.03	130.8	3.6	120.0	4.5	52.3	14.1
		15-65	24	7.8	2.6	0. 39	4.5	3.63	16.66	1.2	15.2	4.0	2.0	6.6
		65-100	24	7.5	7.72	0.11	10.2	6.33	19.75	0.9	15.2	3.5	18.3	5.4
		100-150	24	7.4	3.58	0.05	10.3	7.06	17.68	0.7	9.0	3.5	17.1	6.0
	10	0-40	23	7.2	3.08	0.04	6.8	4.79	17.7	0.7	24.0	2.5	3.6	7.3
		40-90	26	7.6	3.23	0.05	12.1	9.36	10.38	0.8	14.0	3.0	15.9	3.2
		90-130	27	7.6	1.90	0.03	8.0	6.31	4.33	0.3	5.4	2.0	13.0	1.6
	12	0-10	27	7.1	1.69	0.03	1.6	1.68	13.24	0.3	12.3	2.0	2.6	10.3
		10-25	25	8.0	0.67	0. 11	0.9	0.94	4.6	0.2	4.0	2.0	0.7	4.8
		25-55	30	8.3	4.60	0.08	4.8	3.08	38.4	0.8	34.0	3.0	10.1	19.4
Alluvial Plain	11	0-25	32	8.0	1.35	0.02	1.7	0.61	10.54	0.7	9.0	3.5	1.0	9.9
		25-50	20	8.1	0.73	0.34	1.7	0.98	4.12	0.5	3.0	3.0	1.0	2.7
		50-100	26	8.2	0.56	0.031	0.7	0.15	4.56	0.2	3.1	2.5	1.3	7.0
		100-150	22	8.7	0.46	0.47	0.6	0.12	3.71	0.1	3.1	1.00	0.1	8.8
	13	0-20	27	7.9	5.1	0.08	8.4	7.28	39.75	1.2	45.2	3.5	8.0	11.5
		20-65	30	7.7	16.8	0.32	73.6	31.92	138.6	3.0	210.0	3.0	34.1	14.6
		65-150	25	7.9	8.35	0.13	18.6	5.18	84.0	1.6	70.0	3.0	36.4	3.9
	14	0-20	27	7.7	1.89	0.13	5.7	3.85	8.73	0.5	12.0	4.0	2.9	2.8
		20-60	23	7.7	2.22	0.03	9.4	6.26	6.25	0.3	12.0	3.5	6.7	2.2
		60-150	25	7.7	2.41	0.03	10.3	8.50	5.0	0.3	4.0	4.0	16.1	1.6
	15	0-10	28	7.4	48.6	0.87	205.9	241.7	595.0	12.5	800.0	2.0	253.1	39.7
		10-40	27	7.3	37.4	0.64	163.7	162.5	415.5	10.0	620.0	3.0	128.7	32.5
		40-90	27	7.4	15.9	0.27	86.6	58.8	111.5	2.6	220.0	3.0	36.5	10.3
		90-150	22	7.5	23.3	0.32	156.2	99.4	197.5	5.0	430.0	3.0	25.2	13.7

Table (8): Chemical analysis of deep groundwater samples for some wells at Wadi El - Natroun area.

Well No	Well name	pH	EC dS/m	T.D.S (mgL^-)	Cations (mgL^-)				Anions (mgL^-)				SAR	Aquifer Type
					Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^-	B^-		
1	Ground water station	7.6	0.53	340	102	110	131	٧	١٦٩	٣٨	١٣٤	0.0	١٢.٧	Nile Delta Aquifer
2	El - Sharway Farm	7.7	0.5	320	٨٣	١١٥	١٣٠	٦	١٥٥	٤٠	١٣٠	0.4	12.9	Wadi El-Natroun Aquifer
3	El-Ahram Farm	7.5	2.7	1728	٣٨٤	٤١٦	٨٥٠	٦٤	٩١٠	٥٠	٧٧٠	8.0	42.5	Wadi El - Natroun Aquifer
4	Water Distribution Station	7.9	2.34	1500	٩٥	١٢٨	٣٣٢	١٣	٣٠٢	٣٢	٢٠٠	1.5	٣١.٤	El - Moghra Aquifer
5	EL Rowad El -Arab	7.9	2.58	1650	١٠٢	١٥٠	٥١٢	١٦	٤٣٥	٤٢	٣٨٠	0.9	٤٥.٦	El - Moghra Aquifer
6	El - Bostan	7.8	0.56	352	٩٦	١٢٧	١٤٠	١٠	١٦٠	٣٣	١٦٠	0.1	١٣.٢	Nile Delta Aquifer
7	EL- Lams	7.8	0.9	608	٥٥	٧٠	٤٨٠	١٣	٤٥٥	٤٥	١٢٥	1.0	٦٠.٧	Wadi El - Natroun Aquifer
8	EL-Gehaz EL-Markazy Well	9.1	2.77	1741	١٣٥	٢٣٥	١٣٧٠	٢١	١٤٠٠	٥١	٣٨٠	3.5	١٠٠.٧	Wadi El - Natroun Aquifer