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Possibility of the Agricultural Expansion Based on Land and Water Resources Potentialities at the Southern Part of Wadi Qena, Central Eastern Desert, Egypt

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WADI Qena is a one of the largest dry valleys in the Eastern Desert of Egypt. Its southern part is considered as a promising land for the agricultural expansion. It comprises land and water recourses, which could be of quite suitability for agricultural uses. Ten soil profiles were selected to represent the soils in the southern part of Wadi Qena. The soils of the study area were morphologically, physically and chemically investigated. The soil texture varies to some extent, from one geomorphic unit to another; being loamy for soils of fluviatile hummocks, loamy sand for soils of terraces and mouth hills, while it varies between sandy to loamy sand for soils of the wadi plain. They belong to Entisols and Aridisols. The soil evaluation results of the studied soils revealed assessment grades of III, IV, V, and VI for the agricultural uses. The main determining factor facing the expansion of agricultural land in Egypt is the availability of water resources. The investigation of water resources and hydrogeological conditions was performed by carrying out fourteen infiltration tests to determine the spatial variation in the soil characteristics. The infiltration rates decreases at the channel course localities, the infiltration rate is high at the area located out of the channel courses. The total dissolved solids (TDS) of water resources are considered graded from fresh (River Nile and Sanhuriya Canal), fresh to slightly saline (Nubia sandstone aquifer) and moderately saline (Quaternary aquifer). Two groups of groundwater points are distinguished in the trilinear Piper diagram. The first group (Quaternary aquifer) comprises the groundwater of alluvial fan sandstone and outer basin fill, whereas the second group (Nubia Sandstone aquifer) represents groundwater of sandstone and shale facies. The Nubia Sandstone aquifer system forms the most probable and effective recharging source for the Quaternary aquifer through the upward leakage the via deep-seated structural elements. However, there is another source of recharge of the Quaternary aquifer system, which is from the downward infiltration of rainfalls on the Red Sea Mountainous terrains, found to the east and northeast of the study area. The promising areas have been pointed out according to the land and water evaluation.

Keywords: Land, Water resources, Evaluation, Groundwater, Wadi Qena, Eastern Desert, Egypt .

Egypt's strategy for sustainable agricultural development aims to attain food security to cope with the over population, which reached an alarming rate. These strategic goals could be approached only by the optimal allocation and utilization of the available natural resources, including land, water, and human resources, together with the conservation, improvement and development of these resources. In this context, horizontal expansion of land, their reclamation and increasing soil potentiality and increasing productivity through vertical expansion are solutions to meet the population demands.

Wadi Qena is a part of the eastern desert. It is one of the largest basins, where it runs opposite to the Nile River (obsequent wadi) from north to south for two degrees of latitude. It is bound by longitudes 32° 30' to 33° 30' E and latitude 26° 00' to 28° 00' N and covers a total area of about 18000 km^2. The study area lies between longitude 32° 32' to 33° 08' E and latitudes 26° 04' to 26° 45' N covering an area of about 4200 km^2 (Fig. 1). The study area is characterized by good labour resource in the southern Egypt, and is accessible through numerous paved roads and railways.

The climatic conditions of the Eastern Desert of Egypt are characterized by an extreme aridity, high evaporation rate, low relative humidity and a short rainy cool winter. Short account about the various climatic elements is summarized as follows: The mean maximum temperature is 22.7 °. More than eight months per year has a mean monthly maximum air temperature exceeding 30 °, particularly from March to October. The highest temperature is recorded during June, July and August, at Qena Town 40.9°, whereas the lowest value is recorded during January. The annual mean minimum temperature ranges from 6.7 ° to 24.1° during winter, whereas the lowest values are recorded in January and February. However, the monthly average temperature fluctuates between 14.7 ° and 32.4° at Qena Town. The mean annual rainfall is about 5.5 mm and is steadily increasing towards the south, whereas the lowest value is recorded at the southern portion of the area under consideration at Qena. The highest values of relative humidity (66%) are recorded at the northern portion of the area at Wadi Qena.

The geology, surface water, and groundwater of the central part of the Eastern Desert attracted the attention of many workers, among them, Ball (1952); Said (1962); El-Tarabili (1966); Abu El-Ezz (1971); Awad (1981); Shalabi *et al.* (1987); El-Shamy (1988); Khedr (1989); El Rakaiby (1989) and El-Hussaini *et al.* (1994). Information given by these authors revealed that the surface of the Eastern Desert is occupied by different types of rocks belonging to various geological ages from the Pre-Cambrian to Cenozoic eras. Accordingly, the main rock formations occupying the surface of the Eastern Desert could be summarized (Fig. 1).

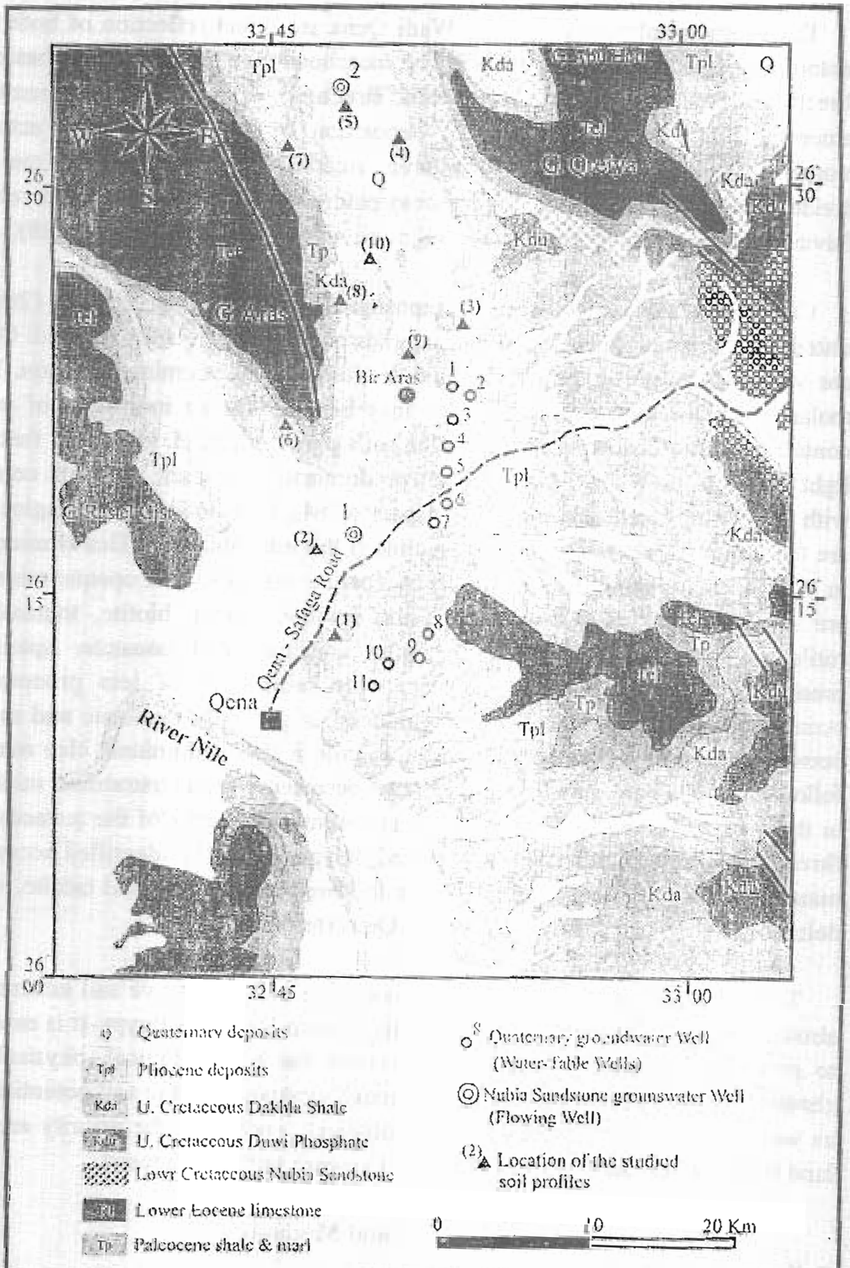

Fig .1. Generalized geological map (EGS, 1979) with water points and locations of the studied soil profiles.

The geomorphologic features of Wadi Qena are direct reflection of both the tectonics and sedimentary processes. The morphotectonic pattern of the basin is directly affected by the Red Sea fault trend structures. It appears that sedimentary processes, colluviation, erosion and deposition by water and wind actions morphed the landscape of the study area. Accordingly the study area can be divided into five local landforms (geomorphic units), namely: tableland relics, fluviatile hummocks, terraces, mouth hills and wadi plains (El-Shamy, 1988).

Concerning the mineralogical composition of Wadi Qena, Hassan (2001), stated that the amorphous inorganic materials contents in the soils of Wadi Qena are very low. Silica is the most abundant, followed by alumina and iron. The molar ratios are low to high and this may be taken as an indication of more contribution of siliceous materials to the soils parent material. He added that the light minerals in Wadi Qena (Quartz) predominates the dark minerals content with less pronounced amounts of feldspars of which orthoclase and plagioclase are the principal members while microcline is the least abundant. Heavy minerals in Wadi Qena minerals are dominated by opaque minerals. Non opaque minerals are dominated by amphiboles, pyroxene, epidote, zircon, biotite, tourmaline, rutile, garnet staurolite, kyanite, silimanite, andalusite and monazite. Apatite is present in moderate amounts, while apatite mineral is of less pronounced occurrence or even absent. The index mineral is generally moderate and raging between 4.4-34.80. He mentioned that Kaolinite is the predominant clay mineral followed by smectite with less pronounced occurrence of interstratified minerals in the soils of the wadi plains, while it is absent in the soils of the terraces and fluviatile hummocks and illite chlorite and palygroskite. The identified accessory minerals are mainly dominated by quartz followed by feldspars and calcite, while dolomite is absent in some soils of Wadi Qena (terraces).

The aim of the current investigation is to give comprehensive soil information about Wadi Qena in the central part of the Eastern Desert of Egypt. It is essential to perform a pedochemical study to evaluate the morphological, physical and chemical properties of its soils. Thus, through evaluation of the soil potentialities, as well as water resources and hydrogeological conditions, the priority areas of land and water efficiency for agricultural purposes will be proposed.

Material and Methods

Soil investigations

Ten soil profiles were chosen to represent the major geomorphic units of the studied area. These profiles were dug deep down to 150 cm, morphologically described and sampled according to FAO (1990) (Fig. 1). The soil samples represent different morphological variations throughout the entire investigated profiles were air-dried, crushed and sieved. Thus following analyses were carried out: Mechanical analysis was carried out by Pipette Method (Richards, 1954). Some physical and chemical analyses were carried out according to Jackson (1967) and Richards (1954).

Moreover, other local environmental features were also registered such as natural vegetation topography, slope, elevation and surface cover. Land evaluation was accomplished according to Sys (1991).

Water resources and hydrogeological conditions

The hydrogeological investigations were carried out through the interpretation of infiltration tests and the obtained hydrogeological and hydrochemical data, which could be summarized as follows:

Infiltration characteristics of Wadi Qena soil: Fourteen infiltration tests were performed using the modified Nestrov double-ring infiltrometer. The purpose of these infiltration tests is to determine the spatial variation in the soil characteristics.

Hydrochemistry: Seven water samples were collected to represent the water resources of the study area. Two samples represent the surface water of Nile River and Sanhuriya Canal, two samples from the Nubia Sandstone aquifer system and three samples from the Quaternary aquifer system. In the present work, special attention was given to the groundwater resources.

Hydrochemical characteristics and groundwater quality evaluation: The chemical analyses were done according to the methods adopted by the US. Geological Survey (USGS) (Rainwater & Thatcher, 1960). The classification of the total concentration of dissolved constituents was carried out as proposed by Hem (1985). The hydrochemical evolution of groundwater is clarified using the trilinear diagram of Piper (1944).

Standard classification of water for agricultural purposes, based on SAR values (based on the U.S. Salinity Laboratory Staff Department of Agriculture (1954). Wilcox classes of electrical conductivity and sodium adsorption ratio for classifying water for irrigation purposes.

Results and Discussion

The topography of the study area is moderately steep slopping, almost flat and gently slope which are represented by profiles no. (1), (3-5), (6-10), respectively, (Table 1). The elevation of the area ranges between 80 and 117 m above see level. The studied soils have deep profile; it ranges from 100 to 170 cm. They are well drained soils. The structure is single grains or massive.

TABLE 1. Some morphological characteristics of the investigated soil profiles representing Wadi Qena, Eastern Desert, Egypt.

Geomorphic unit	profile No.	Elevation (m) A.S.L.	Topography	Agric. Landuse	Drainage	Subgreatgroup
Mouth hills	1	112	Mod. Steep slope	Barren	Well	Typic Torrifluvents
Wadi plains	2	115	almost flat	Barren	Well	Typic Haplocalcids
	3	100	almost flat	Barren	Well	Typic Torrifluvents
	4	86	almost flat	Barren	Well	Typic Calcigypsids
	5	107	almost flat	Barren	Well	Typic Haplocalcids
Terraces	6	84	Gently sloping	Barren	Well	Typic Torrifluvents
	7	82	Gently sloping	Barren	Well	Typic Torrifluvents
Fluviatile hummocks	8	60	Gently sloping	Barren	Well	Typic Calcigypsids
	9	80	Gently sloping	Barren	Well	Typic Calcigypsids
	10	80	Gently sloping	Barren	Well	Typic Haplosalids

Physical and chemical properties of Wadi Qena soils

Soil texture is generally sandy, loamy sand, sandy loam and loamy and varies to some extent, from one geomorphic unit to another, being loamy for soils of fluviatile hummocks, loamy sand for soils of terraces and mouth hills, whereas it varies from sandy to loamy sand for soils of wadi plain, (Table 2). Soils salinity differs appreciably from one locality to another. For instance, soils of the mouth hills are slightly saline, while the soils of wadi plain are non to strongly saline. Soils of fluviatile hummocks are moderately to strongly saline, and terraces are slightly to strongly saline.

Soil reaction is generally neutral to moderately alkaline as shown by the pH values, which range from 6.6 and 8.1. The values of pH tend to be slightly acidic in some layers, which are very strongly saline in fluviatile hummocks unit. The total carbonate content is very high, which is due to their limestone origin. This indicates a non-calcareous nature of the soils. Gypsum content is relatively very low except for the fluviatile hummocks unit. Organic matter content is generally very low. It ranges from 0.08 to 0.70 %, owing to the prevalence of arid conditions, which facilitate the decomposition of the organic matter (Table 2).

The soil classification was performed following the American System "Soil Taxonomy", (USDA, 2003). The studied soils were classified into two soil orders, namely Entisols, Aridisols and summarized in Table 1 .

TABLE 2. Some physical and chemical composition of the soil paste extract saturation of the studied soil profiles.

Prof. No.	Depth (cm)	Gravels % (V)	Particle size distribution % Sand	Silt	Clay	Texture class	PH 1:2.5	EC dS/m	$CaCO_3$ %	O.M %	Gypsum %
1	0 - 60	20.0	88.5	6.0	5.5	L.S.	7.9	7.38	16.5	0.18	0.40
	60 - 100	9.0	83.0	10.0	7.0	L.S.	7.6	6.76	17.8	0.23	0.35
	100 - 150	6.6	85.0	6.9	8.1	L.S.	7.8	7.49	25.6	0.17	0.57
2	0 - 25	8.0	65.5	19.2	15.3	S.L.	7.5	3.45	15.9	0.10	0.70
	25 - 40	33.0	67.1	20.2	12.7	G.S.L.	7.3	39.00	18.7	0.17	1.90
	40 - 70	22.0	70.2	19.0	10.8	S.L.	8.0	65.00	21.5	0.35	2.40
	70 - 100	19.0	80.2	10.8	9.0	S.L.	7.9	41.30	11.5	0.18	0.60
	100 - 130	18.5	68.1	16.0	15.9	S.L.	7.7	42.90	16.0	0.26	0.75
3	0 - 10	24.0	91.1	6.2	2.7	L.S.	7.9	11.00	20.1	0.09	0.39
	10 - 16	56.0	98.9	0.4	0.7	VGS	7.6	5.60	17.3	0.10	0.24
	16 - 60	19.0	97.6	1.0	1.4	S	7.7	2.00	20.3	0.16	0.19
	60 - 80	32.8	96.8	2.0	1.3	GS	8.0	9.95	11.1	0.12	0.16
	80 - 120	60.0	91.9	2.5	5.6	VGS.L	7.8	15.00	16.0	0.08	0.31
4	0 - 50	36.5	82.4	13.0	4.6	GS.L.	8.1	4.31	18.0	0.16	4.00
	50 - 100	49.2	95.2	2.8	2.0	GL.S.	7.8	18.95	26.3	0.15	6.10
	100 - 160	50.6	95.7	2.7	1.6	VGL.S	7.4	80.00	23.5	0.12	3.20
5	0 - 35	5.0	31.0	49.5	19.5	Si.L.	7.8	1.16	25.6	0.28	0.71
	35 - 60	8.2	61.7	21.8	16.1	S.L.	8.1	1.00	26.7	0.39	0.13
	60 - 75	24.9	92.7	3.5	3.8	S	8.0	1.21	19.1	0.30	0.21
	75 - 140	18.5	45.3	19.4	35.3	C	7.9	1.59	18.1	0.45	0.16
6	0 - 40	26.6	71.6	16.9	11.5	GS.L.	7.8	60.60	21.2	0.70	0.55
	40 - 50	24.0	91.8	4.9	3.3	L.S.	8.1	18.05	33.4	0.17	0.85
	50 - 100	21.3	97.3	1.4	1.3	S	7.9	6.20	40.5	0.16	0.60
7	0 - 17	42.8	94.3	2.9	2.8	GS	7.6	10.95	34.0	0.09	0.19
	17 - 60	15.5	36.7	43.3	20.0	L	7.5	58.00	25.5	0.35	0.39
	60 - 100	28.3	97.1	1.9	1.0	GS	8.0	15.50	33.0	0.26	0.42
8	0 - 10	20.8	54.0	35.5	10.5	Si.L.	8.0	10.18	31.4	0.18	6.30
	10 - 60	18.5	4.8	52.5	42.5	Si.C.L.	7.7	69.00	40.6	0.38	3.20
	60 - 170	12.3	18.5	58.8	22.7	Si.L.	8.1	8.10	34.6	0.27	3.80
9	0 - 40	40.5	97.3	1.0	1.7	GS	7.6	21.00	29.7	0.43	1.90
	40 - 140	18.5	3.7	68.7	27.6	Si.L.	8.0	16.00	41.3	0.38	2.10
	140 - 170	12.3	24.4	56.6	19.0	Si.L.	7.9	59.90	18.6	0.22	4.10
10	0 - 15	21.0	85.3	9.2	5.5	L.S.	6.6	153.00	32.1	0.38	2.60
	15 - 90	15.6	21.0	44.6	34.4	C.L.	6.9	179.00	29.9	0.51	3.90
	90 - 120	20.8	5.0	53.5	41.5	Si.C.	6.8	169.30	36.4	0.67	3.60

Land evaluation

The capability indices of the studied soil profiles reveal that the studied soils of Wadi Qena are placed between (III) and (VI) grades (Table 3 & Fig. 2) as follows:

1. Grade (III): Fair soils include profile no. 5.
2. Grade (IV): Poor soils represented by profiles no.1, 3 and 8.
3. Grade (V): Very poor soils include profiles no.2, 4, 6, and 7.
4. Grade (VI): Non agricultural soils represented by profile no. 9 and 10.

Water resources and hydrogeological conditions

The hydrogeological investigations were carried out through the interpretation of infiltration tests and the interpretation of the obtained hydrogeological and hydrochemical data, which could be summarized as follows:

Infiltration characteristics

The purpose of these infiltration tests is to determine the spatial variation in the soil characteristics. Soil infiltration characteristics were determined and are summarized in Table 4 according to Philip (1957). The infiltration tests were performed at the central part of the study area (Fig. 1). The calculated infiltration rates ranged between 1.4 and 69.5 cm/h. The wide variation in the calculated values could be attributed to the wide variation in the soil textures (Konknke, 1980) as revealed from the soil texture map (Fig. 3).

The results of these tests show that the ultimate infiltration capacities range between 1.4 and 69 cm/h. It is obvious that the infiltration rates decreases at the channel course localities (infiltration tests no. 1 & 6), where the soil is silty and compacted. On the other hand, infiltration rate is high at the area located out of the channel courses, where the soil is mainly composed of sands and gravel (infiltration tests no. 2, 5, 7 and 13) (Fig. 3).

Hydrochemistry

Hydrochemical characteristics and groundwater quality evaluation

The chemical analysis of groundwater is very important in determining its quality for the different uses. It also reflects the origin of water and its relation to the climate and geology of the area.

The study area comprises thirteen-water wells. Two of them are flowing, tapping the artesian Nubia Sandstone aquifer system, whereas the other eleven wells are shallow, and tapping the Quaternary water-table aquifer (Fig. 1). Only three of these shallow wells are productive, whereas the rest are abandoned or dry. The chemical analyses are carried out to define primarily the suitability of water in terms of its potential uses for domestic and agricultural purposes, sources of recharging, origin of mineralization and water evolution. The chemical analyses include sodium, potassium, calcium, magnesium, chloride, bicarbonate and sulphate. The chemical analyses were carried out according to the methods adopted by the USGS (1984) and Rainwater & Thatcher (1960).

TABLE 3. Land capability index for the studied soil profiles.

Profile No.	available irrigation water	Texture Grade	profile depth	Wetness drainage condition	Salinity level	Sodicity %	CaCO3 %	Gypsum %	Slope %	Capability index	Grade symbole	indication
1	90	58	100	100	85	80	75	100	70	26.62	IV	poor soils (2) *
2	90	75	100	100	35	60	60	100	100	11.34	V	Very poor soils (3)
3	90	62	100	100	85	75	85	100	100	30.23	IV	Poor soils (2)
4	90	63	100	100	45	80	70	95	100	13.57	V	Very poor soils (3)
5	90	80	100	100	100	100	60	100	100	43.20	III	Fair soils (1)
6	90	69	90	100	45	93	60	100	95	14.03	V	Very poor soils (3)
7	90	68	90	100	45	100	60	100	95	14.87	V	Very poor soils (3)
8	90	90	100	100	45	100	65	95	95	22.50	IV	Poor soils (2)
9	90	80	100	100	35	45	60	100	95	6.80	VI	Non agric. Soils (4)
10	90	90	100	100	25	70	65	95	95	8.75	VI	Non agric. Soils (4)

*Number designates to priority index

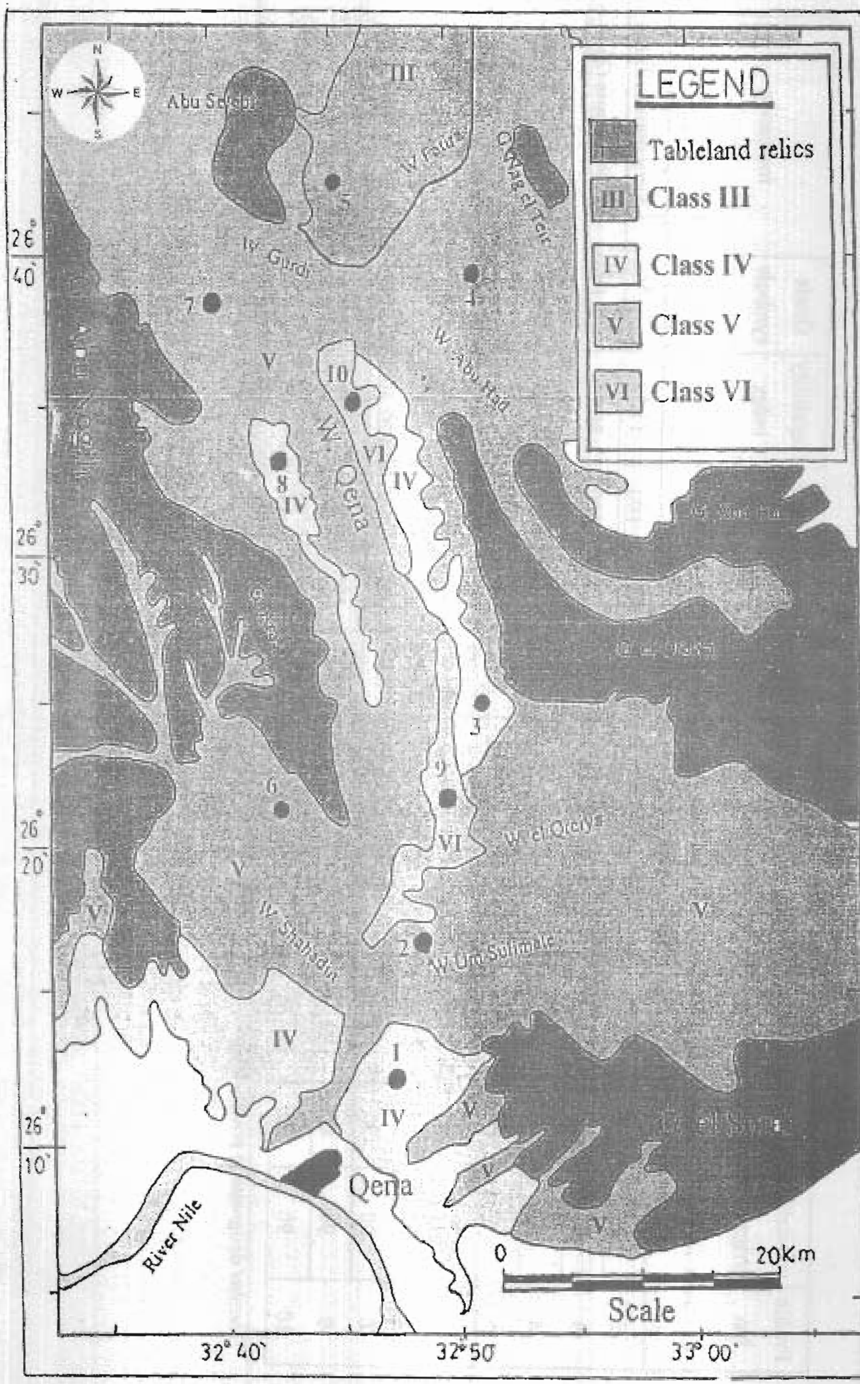

Fig.2. Land capability map of the study area.

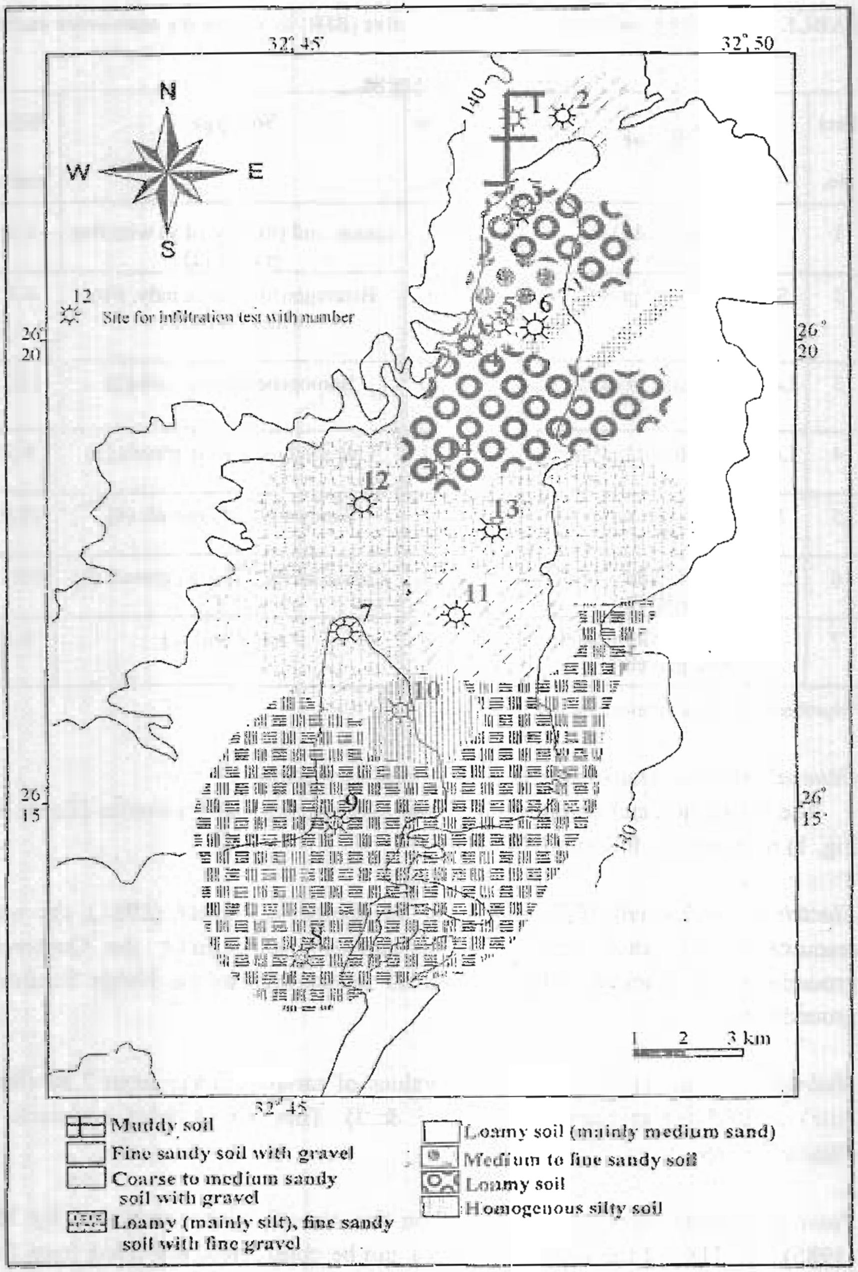

Fig. 3. Soil texture classes and locations of infiltration tests carried out at the study area.

TABLE 4. Soil types and basic infiltration rates (BIR) at which the tests were carried out .

Test No.	Soil type	BIR cm/h	Test No.	Soil type	BIR cm/h
1	Muddy soil (1)*	1.6	8	Loamy soil (mainly silty) with fine gravels (2)	1.4
2	Sandy soil with gravels (4)	27.8	9	Heterogeneous fine sandy, silty with gravels (3)	6.5
3	Loamy soil (mainly silts) (2)	5.5	10	Homogeneous silty soil (2)	12.3
4	Loamy soil (mainly silts) (2)	3.8	11	Fine sandy soil with gravels (3)	9.5
5	Medium to fine sandy soil (5)	18.4	12	Sandy soil with gravels (4)	28.0
6	Loamy soil (mainly medium sands) (2)	2.5	13	Coarse sandy soil with gravels (6)	69.5
7	Coarse to medium sandy with gravels (4)	24.9	14	Loamy soil (2)	8.1

*Number designates to priority index

General chemical characteristics of groundwater aquifers

The hydrochemical composition of the investigated water samples (Table 5 & Fig. 1) revealed the following features:

Electrical conductivity (EC): According to Mandel & Shiftan (1981), the water resources in the study area could be classified as follows: the Quaternary groundwater is brackish, while it is fresh to brackish in the Nubia Sandstone groundwater.

Hydrogen ion activity (pH): The pH values of samples range from 7.80 (River Nile) to 8.45 (Quaternary Wells no. 1 & 3). Thus the samples approach the alkaline range.

Total dissolved solids (TDS): Based on the classification mentioned by Hem (1985), the TDS of the investigated area can be considered as graded from fresh (River Nile and Sanhuriya Canal), fresh to slightly saline (brackish) (Nubia sandstone aquifer) and moderately saline (Quaternary aquifer). The relative increase of salinity of the Quaternary aquifer is perhaps due to the leaching and seasonal climatic factors.

TABLE 5. Results of chemical analyses of water samples from Wadi Qena.

Serial No.	Water resource	pH	EC dS/m	TDS	Soluble cations (meq/l)				Soluable anions (meq/l)			SAR
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^-	Cl^-	
1	River Nile	7.8	0.29	205	2.0	1.2	1.3	0.2	3.2	0.2	0.8	1.0
2	Nubia S.S. no. 1	8.0	3.10	2080	1.1	2.0	31.4	0.0	10.7	8.3	15.6	25.2
3	Nubia S.S. no. 2	7.9	2.70	1200	1.7	1.7	20.3	0.0	3.4	5.4	14.8	15.7
4	Sanhuriya Canal	7.9	0.31	208	1.5	1.4	1.3	0.2	2.9	0.2	0.9	1.1
5	W.1 (Q)	8.4	4.60	3055	6.6	10.3	47.8	0.3	16.2	20.6	27.8	16.4
6	W.2 (Q)	8.2	5.50	4025	10.8	15.4	56.5	0.6	5.6	20.7	49.2	15.6
7	W.3 (Q)	8.4	6.00	4890	12.4	13.8	55.7	0.9	3.0	40.5	53.2	15.4

Classification and origin of mineralization

The sequence of ion dominance of major cations and anions in the groundwater follows the order Na > Mg > Ca and Cl > SO_4 > HCO_3 in Wells no. 1, 2 & 3, Na > Mg > Ca and HCO_3 > Cl > SO_4 in the Nubia Sandstone flowing well no. 1 and Na > Mg > Ca and Cl > SO_4 > HCO_3 in Nubia Sandstone flowing Well no. 2 . So that, the prevalent chemical water types are chloride-sodium and bicarbonate-sodium, pertaining to the ultimate phase of metasomatism.

The hydrochemical evolution of groundwater in the investigated area is clarified using the trilinear diagram of Piper (1944). Three groups of points are distinguished in the diamond-shaped field. The first group occupies the lower right side of the upper triangle (Wells no. 1, 2 & 3), the second group (Nubia Sandstone aquifer) occupies the lower triangle, whereas the third group occurs at the contact between the two triangles (River Nile and Sanhuriya Canal). Generally, the water, which appears in the upper triangle, has secondary salinity properties (mixing origin) (where sulphate and chloride exceed sodium and potassium). On the other hand, those, which appear in the lower triangle, are considered to have primary alkalinity properties (where carbonate and bicarbonate exceed calcium and magnesium). River Nile and Sanhuriya Canal samples occur at the interface of the two triangles, where fresh surface water is revealed. By plotting the chemical data on the Piper diagram, one can identify geologic units with chemically similar water, and define the evolution in water chemistry along a flow system (Back, 1961).

Thus, two groups of groundwater points are distinguished in the diamond-shaped field. The first group (Wells no. 1, 2 & 3 of Quaternary aquifer) comprises the groundwater of alluvial fan sandstone and outer basin fill, whereas the second group (Nubia Sandstone aquifer) represents groundwater of sandstone and shale facies. However, the first and second groups reveal the NaCl, Na_2SO_4 water type, which designates to meteoric or marine origin during reduction processes. The field occurrence of the drilled Quaternary wells in the vicinity of the confined

Nubia Sandstone aquifer zone of the southern part of Wadi Qena, gave the fingerprint of mixing origin of the groundwater of the Quaternary aquifer. The Nubia Sandstone aquifer system form the most probable and effective recharging source for the Quaternary aquifer through the deep seated structural elements prevailing in the study area (Fig. 4). The same idea is reinforced by the results obtained from the interpretation of the hydrochemical data using Piper diagram, as previously mentioned.

In other words, the comparison between the equipotentiometric levels of the Nubia Sandstone aquifer system of the southern part of Wadi Qena (Elewa *et al.* 2001) (Fig. 4), with those of the Quaternary aquifer system for the same area (Fig. 5) indicates that the Nubia aquifer system, to a large extent, constitutes a main recharge source for the Quaternary aquifer. The equipotentiometric levels of the Nubia aquifer system are higher than those of the Quaternary one, which gives the chance for a hydraulic connection between the two aquifers to take place through the deep seated faults and fractures. The equipotentiometric map of the Quaternary aquifer system reveals that the maximum potentiometric level was encountered at the northeastern part of the mapped area (contour 120), whereas the minimum value was attained at the southwestern part of the study area (contour 80). This reveals that the Quaternary aquifer is also recharged from the northeastern part of the study area (Fig. 5). The direction of groundwater movement in the Quaternary aquifer system is from northeast to southwest, which reflects another source of recharge through the downward infiltration of rainfalls on the Red Sea Mountainous terrains, found to the east and northeast of the study area.

Groundwater evaluation for agricultural uses

Evaluation of the water used for irrigation is based on the sodium concentration in the water, as it reacts with the soil and reduces the permeability and or alter its characteristics.

The sodium adsorption ratio (SAR), which is used by the Salinity Laboratory Staff of the US Department of Agriculture (1954) as a standard measure for such uses is here considered. While a high salt concentration in water leads to the development of alkali soil. Irrigation water with low (SAR) is desirable:

By comparing the SAR results of water samples collected from Wadi Qena (Table 5), with the standard classification of SAR (US Salinity Laboratory Staff, 1954), the groundwater in the study area ranges from good for preferable use on coarse texture with good permeability soil (Nubia Sandstone flowing Well No. 2 & Quaternary Wells Nos. 2 and 3) to fair and can cause harmful effects to plants under normal conditions of irrigation in the other wells.

The most common nomogram, which is used in evaluating the suitability of water for irrigation by the US Salinity Laboratory Staff, 1954 and Wilcox, 1955 is a plot of specific conductivity, which is a function of total dissolved solids, against the sodium adsorption ratio (Fig. 6).

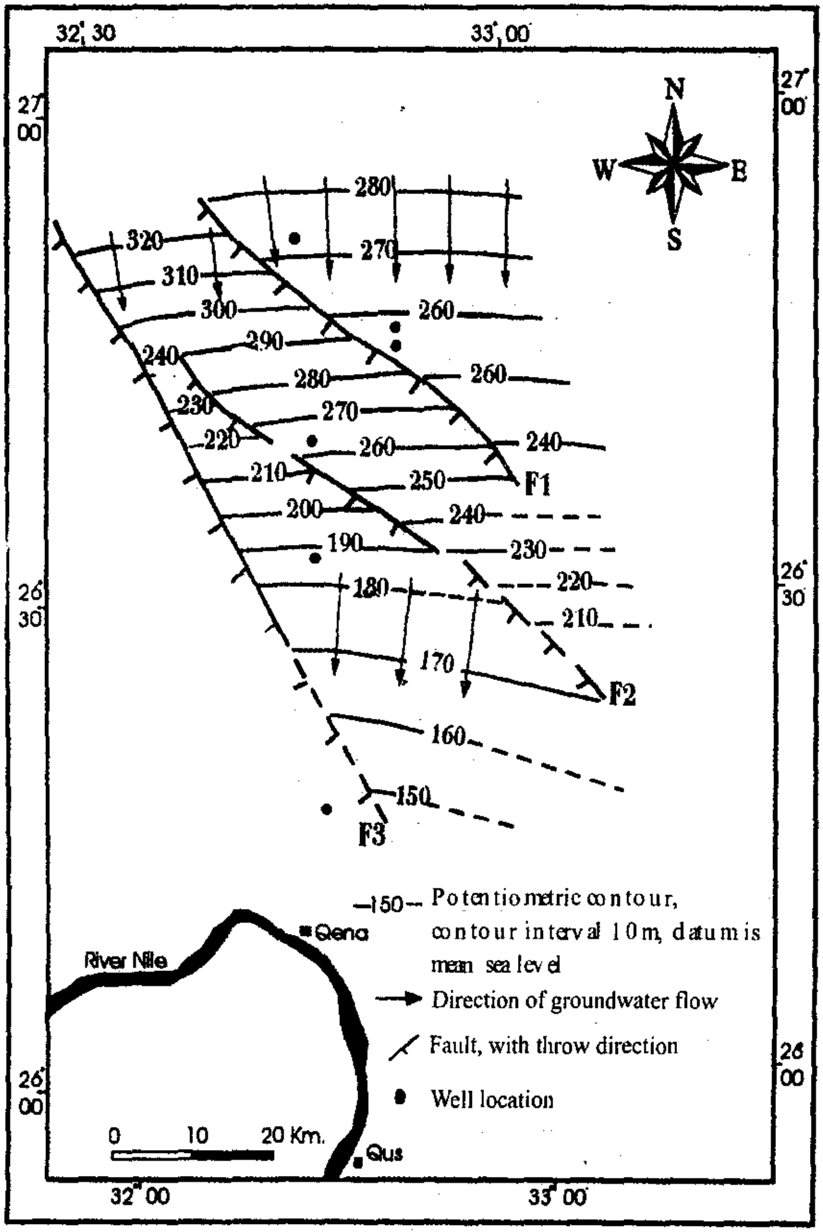

Fig. 4. Equipotentiometric map of the Nubia sandstone aquifer of the Southern part of Wadi Qena (Elewa *et al.*, 2001).

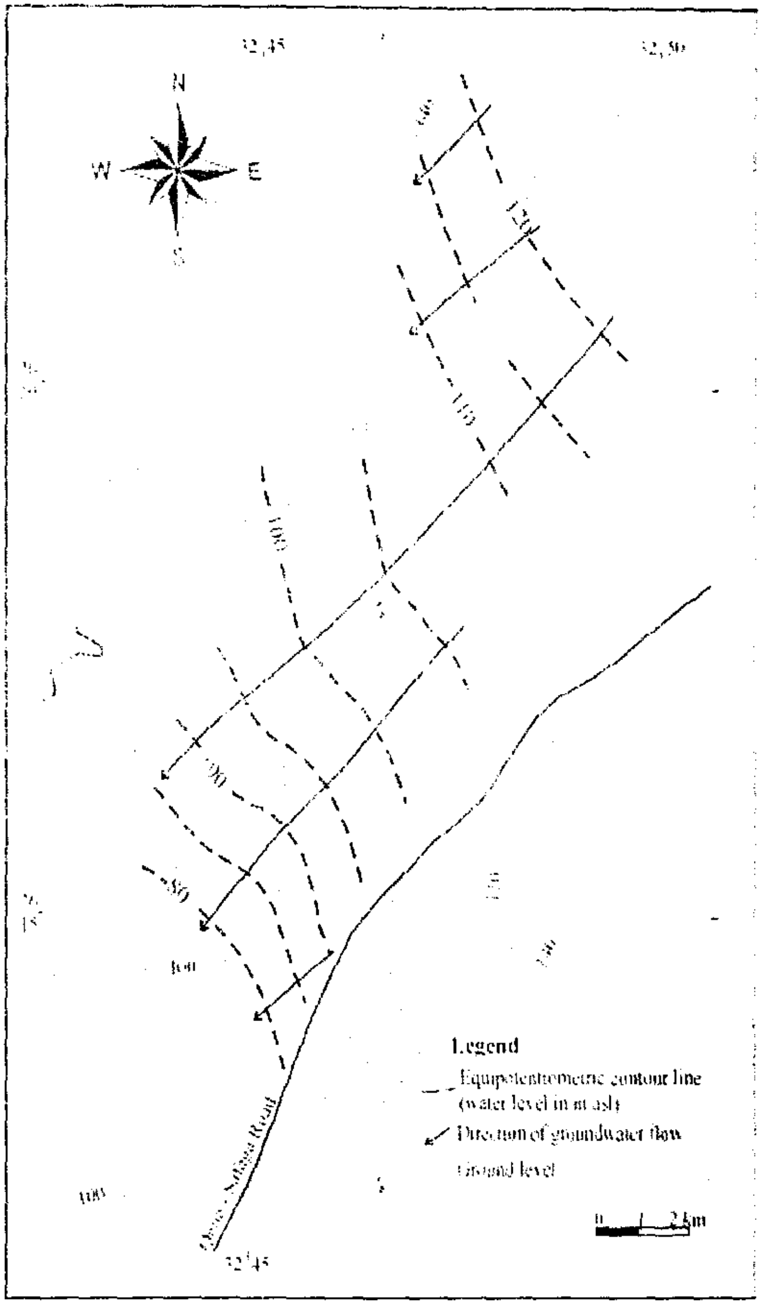

Fig. 5. Equipotentiometric map of Quaternary aquifer system in the Southern part of Wadi Qena.

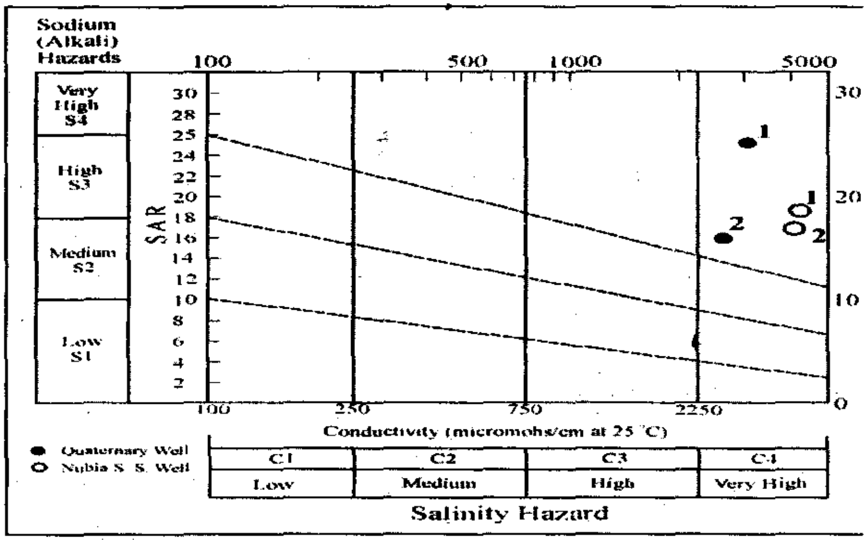

Fig.6. Classification of irrigation water in the study area using Wilcox diagram.

According to the US Salinity Laboratory Staff (1954), the water is divided into classes C1, C2, C3, and C4, which denote to the conductance and S1, S2, S3, and S4, which designate the SAR. The group of water points belonging to both the Quaternary and Nubia Sandstone aquifers are following class (C4-S4), which is characterized by very high salinity hazards and very high SAR. This type of water is not suitable for irrigation under ordinary conditions, but it may be used under special circumstances, i.e. the soil must be permeable, drainage must be adequate, irrigation must be applied in excess to provide considerable leaching, and selection of high salt tolerant crops.

Evaluation of groundwater for drinking and domestic purposes

Depending on the standards recommended by the World Health Organization (1971), the hydrochemical composition revealed that the groundwater in the Nubia Sandstone Well No. 2 is unsuitable to relatively permissible under certain conditions (1200 ppm), whereas the other water points of the Quaternary and Nubia aquifer is unsuitable to satisfactory (due to its higher salinity hazards) for human drinking (Table 6).

TABLE 6. Evaluation of groundwater for drinking and domestic purposes (WHO, 1971).

TDS (ppm)	Evaluation for drinking purposes
500	Excellent (1)*
1500	Permissible (2)
> 1500	Unsuitable to satisfactory (3)

* Number designates to priority index

Water required for domestic purposes on farms includes that consumed by the livestock and poultry is subjected to quality limitations of the same type as those relating the quality of drinking water for human consumption. (National Academy of Science, 1972), accordingly, the following can be deduced:

a- Excellent water for all classes of livestock and poultry (TDS ≤1000 ppm) includes none of the water points in both the Nubia or Quaternary aquifers. (1)

b- Very satisfactory water for all classes of livestock and poultry (TDS ranges from 1000 to 3000 ppm) comprises the groundwater of Nubia Sandstone Wells No. 1 & 2 and somewhat the Quaternary water Well No. 1. (2)

c- Satisfactory water for livestock (3000-5000 ppm) includes all the other water points of Quaternary and Nubia Sandstone aquifer water wells. (3)

Priority of land use map

The superposing of the previously discussed water resources and soil investigations resulted in the construction of land capability map. This map shows the capability classes in terms of priorities in the light of suitable uses. Four areas of priority for agricultural and water uses were established according to an index proposed from the previously mentioned water resources and soil investigation criteria. The determining criteria include; soil type, water characteristics, water for agricultural use, water for human drinking, water resources availability (Nubia Sandstone & Quaternary aquifer), water depth, infiltration rate and water for livestock consumption. The created index for each classification category was initiated in descending order (*i.e.*, from 1 to 3, 1 to 6, etc...). In case of the infiltration rate determining criterion for the agricultural suitability of land; 1 is a figure designating to a somewhat low infiltration rate, while 6 designates to very high infiltration rate. However, from the infiltration rate point of view, the lower or medium infiltration rate may be better than the higher or very high infiltration rate of soil, which is related to what is called the water retention capacity of the soil. According to the priority index four priority areas for water and land use were determined (Table 7 & Fig. 7).

TABLE 7. Priority classes of land use according to the created priority index.

Category Priority areas	Soil Type (1-6)	Water salinity (1-5)	pH value (1-3)	EC (1-6)	Water for agricultural use (1-4)	Water for human drinking use (1-3)	Water resources availability (1-3)	Water depth (1-4)	Infiltration rate (1-6)	Livestock consumption (1-3)
I	1 - 2	2 - 3	2	4	2 - 3	3	1-2	3	1	2 - 3
II	2 - 3	2 - 3	2	4	2 - 3	3	1-2	2	4	2 - 3
III	2	2 - 3	2	4	2 - 3	3	1-2	4	2	2 - 3
IV	4	0	0	0	0	0	0	1	2	0

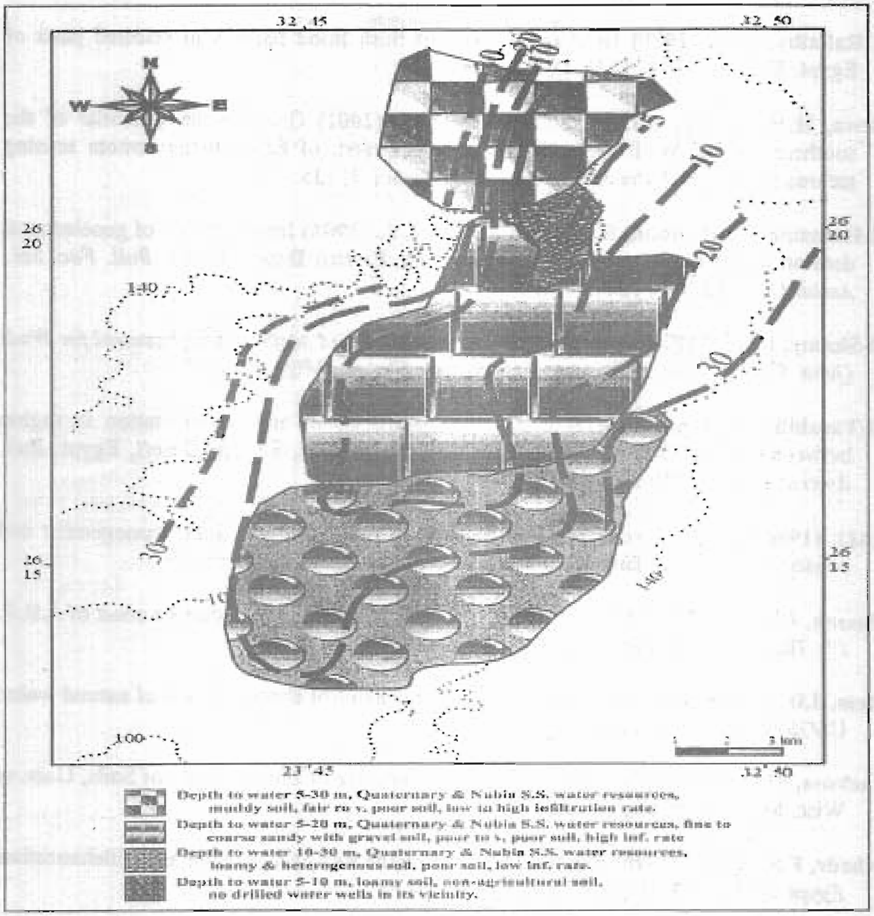

Fig. 7. Priority of land use map, based on water resources availability, soil characteristics, infiltration capacities and depth to water in the Quaternary aquifer.

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دراسة إمكانية التوسع الزراعي معتمدا علــى المــوارد الأرضــية والمائية الكامنة في جنوب وادي قنا بالصحراء الشرقية-مصر

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شعبة الموارد المائية - الهيئة القومية للاستشعار عن البعـد وعلــوم الفضــاء - القاهرة و * معهد الأراضي والمياه والبيئة-مركز البحوث الزراعيــة - القــاهرة و** قسم الأراضي واستغلال المياه- المركز القــومي للبحــوث - القــاهرة - مصر .

يعتبر وادي قنا من اكبر الوديان الجافة في الصحراء الشرقية المصرية كما يعتبر الجزء الجنوبي لهذا الوادي من المناطق الواعدة لإمكانات التوسع الزراعي من حيث توافر مصادر المياه والتربة المناسبة لهذا التوسع. تم اختيار عدد ١٠ قطاعات أرضية تمثل مختلف أنواع التربة في المنطقة الجنوبية من وادي قنا. وتم دراسة هذه القطاعات جيومورفولوجيا وفيزيائيا وكيميائيا. ويتميز قوام تربة منطقة الدراسة بالقوام الرملي، الرملى الطميى، الطميى الرملي، والطميى. وتتفاوت خصائص التربة من وحدة جيومورفولوجية لأخرى، حيث تتبع رتبتى Entisols, Aridisols حسب التقسيم الامريكى (٢٠٠٣). واشارت نتائج تقييم أراضي منطقة الدراسة الى انها تتبع درجات من III إلى VI من حيث صلاحيتها للاستخدام الزراعي.

وحيث أن أهم عامل محدد لصلاحية الأراضي للتوسع الزراعي بمنطقة الدراسة هو توافر مصادر المياه الجوفية، فقد تم دراسة هذه المصادر من خلال إجراء ١٤ تجربة إرتشاح (تسرب سطحي) للتعرف على التفاوت الفراغي لخصائص التربة. وقد تبين أن معدلات التسرب تقل في مناطق مسارات الوديان (تجارب الإرتشاح أرقام ١ و٦) حيث تتكون التربة من الطين المضغوط. على الجانب الآخر تتزايد معدلات الإرتشاح في المناطق الواقعة خارج مسارات الوديان حيث تتكون التربة أساسا من الرمال والحصى (تجارب الضخ أرقام ٢، ٥، ٧، ١٣). وتم جمع سبعة عينات مائية لتمثيل مصادر المياه بمنطقة الدراسة. وتتفاوت ملوحة المياه من المياه العذبة (مياه النيل وترعة السنهورية)، إلى العذبة المائلة للملوحة (في خزان الحجر الرملي النوبي) إلى متوسط الملوحة (خزان العصر الرباعي). ولقد تم تمييز مجموعتان على نموذج بيبر، حيث تشير المجموعة الأولى (آبار أرقام ١ و٢ و٣) التابعة لخزان العصر الرباعي والذي يختزن مياه جوفية في رواسب المراوح الفيضية الرملية والحشوات الرملية حول الوديان، بينما المجموعة الثانية (خزان الحجر الرملي النوبي) تمثل نوعية مياه جوفية مستخرجة من سحنة الحجر الرملي والطفال. وتعكس كلا المجموعتين أنماط المياه $Na\ Cl, Na_2\ SO_4$ والتي تعكس الأصل الجوي أو البحري أثناء عمليات الاختزال. ولقد تتبين أن خزان الحجر الرملي النوبي يمثل المصدر الرئيسي لشحن خزان العصر الرباعي من خلال التراكيب الجيولوجية العميقة ومقارنة مناسيب المياه لكل من الخزان النوبي والخزان الرباعي ودراسة التطور الكيميائي على نموذج بيبر. وتتحرك المياه الجوفية في خزان العصر الرباعي من الشمال الشرقي الى الجنوب الغربي والتي تعكس وجود مصدر آخر لشحن المياه من خلال الأمطار الساقطة على جبال البحر الأحمر الواقعة إلى الشرق و الشمال الشرقي لمنطقة الدراسة.

واعتمادا على نتائج الدراسة السابق ذكرها تم تحديد أولويات المناطق فى التوسع الزراعي بناء على تقييم الموارد الأرضية والمائية بها.