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RESEARCH ARTICLE

SOIL MAPPING OF WEST MENIA AREA, EGYPT USING REMOTE SENSING AND GIS TECHNIQUES.

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Manuscript Info	Abstract
……………………. *Manuscript History* Received: 08 August 2019 Final Accepted: 10 September 2019 Published: October 2019 *Key words:-* Soil Mapping, GIS, Remote Sensing, Egypt .	…………………………………………………………………… The Western Menia area represents one of the highest priority areas for future development in the country. The studied area is located between 27° 53′ 20.11″ – 27° 58′ 48.34″ North and 30° 06′ 41.53″ – 30° 13′ 6.57″ East and represents an area of about 9078 Feddans.

The Western Menia area represents one of the highest priority areas for future development in the country. The studied area is located between 27° 53′ 20.11″ – 27° 58′ 48.34″ North and 30° 06′ 41.53″ – 30° 13′ 6.57″ East and represents an area of about 9078 Feddans.

Using geological map, Digital Elevation Model (DEM) and visual interpretation of satellite data, a physiographic soil map was produced to present mapping units of the studied area. The area under investigation was classified into two landscapes, i.e. alluvial plain (4181 Feddans, 46.06 % of the total studied area) and terraces (4897 Feddans, 53.94 % of the total studied area)

This study aims to assess and mapping soil properties for salinity, sodicity, lime, gypsum, depth and texture.

Land capability was used to evaluate the soils of studied area. According to Sys model, the studied area was classified into four capability subclasses, i.e. S_2x, S_3t, S_3d and S_3d, t. The soils of S_2x have moderate limitations for agricultural crops, whereas texture is the most limiting factor (48.55 % of the total area). The most limiting factor of soils of S_3t is topography (12.89 %), while the soils of S_3d (27.89 % of the total studied area) whereas the depth is the most limiting factor. On other, hand the soils of S_3d, t (10.66 % of the total studied area) whereas the depth and topography are the main limiting factor for agriculture.

Soil fertility maps were conducted for macronutrients and micronutrients.

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Introduction:-

Desert and uninhabited land represent approximately 95% of the total area of Egypt. Consequently, the majority of the population is concentrated around the Nile River. This unbalanced distribution of inhabitants causes serious social and economic problems, such as the fact that the ever-increasing population has resulted in a decrease in agricultural area per capita from 0.13 ha in 1947 to 0.05 ha in 2004 (FAO, 2005). This value

The studied area is considered as a main region that represents one of these promising land resources in the Western Desert of Egypt, which is needed for the agricultural development facing the pressure of the inevitable food requirement.

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In recent years, thematic mapping has undergone a revolution as the result of advances in geographic information science and remote sensing. For soil mapping archived data is often sufficient and this is available at low cost (Green, 1992).

GIS was used to identify the potential for certain irrigated agriculture for some soils in Western Desert, Egypt (Ismail et al., 2012)

Green, 1992 stated that integration of Remote Sensing within a GIS database can decrease the cost, reduce the time and increase the detailed information gathered for soil survey. Particularly, the use of Digital Elevation Model (DEM) is important to derive landscape attributes that are utilized in land forms characterization (Brough, 1986)

Satellite remote sensing (RS) in conjunction with geographic information system (GIS), have been widely applied and recognized as a powerful and effective tools in analyzing land use categories (Ehlers et.al, 1990; Harris & Veturea 1995 and Weng, 2001). GIS provide indispensable tools for decision makers. Both RS and GIS techniques are considered very important geometric tools, which are fully utilized in the developing countries (Arafat, 2003). The integration of remotely sensed data, GIS and spatial statistics provides useful tools for modeling variability to predict the distribution, presence, and pattern of soil characteristics (Kalkhan et al., 2000). The potential of the integrated approach in using GIS and RS data for quantitative land evaluation has been demonstrated by Martin & Saha (2009).

Land capability is very important step in the reclamation process of the desert to determine the capability of soil cultivation to meet the requirement of the population. To make the evaluation were used by Sys rating systems a methodology produced by Sys *et al.* (1991). The Sys rating systems were suggested under the structure of the FAO Framework for Land Evaluation (FAO, 1976).

The objectives for this study are: (a) producing soil properties maps. (b) evaluating land capability in current and potential. (c) producing soil fertility maps.

Materials And Methods:-
Location
The Studied area is located between 27° 53′ 20.11″ – 27° 58′ 48.34″ North and 30° 06′ 41.53″ – 30° 13′ 6.57″ East and represents an area of about 9078 Feddans (1).
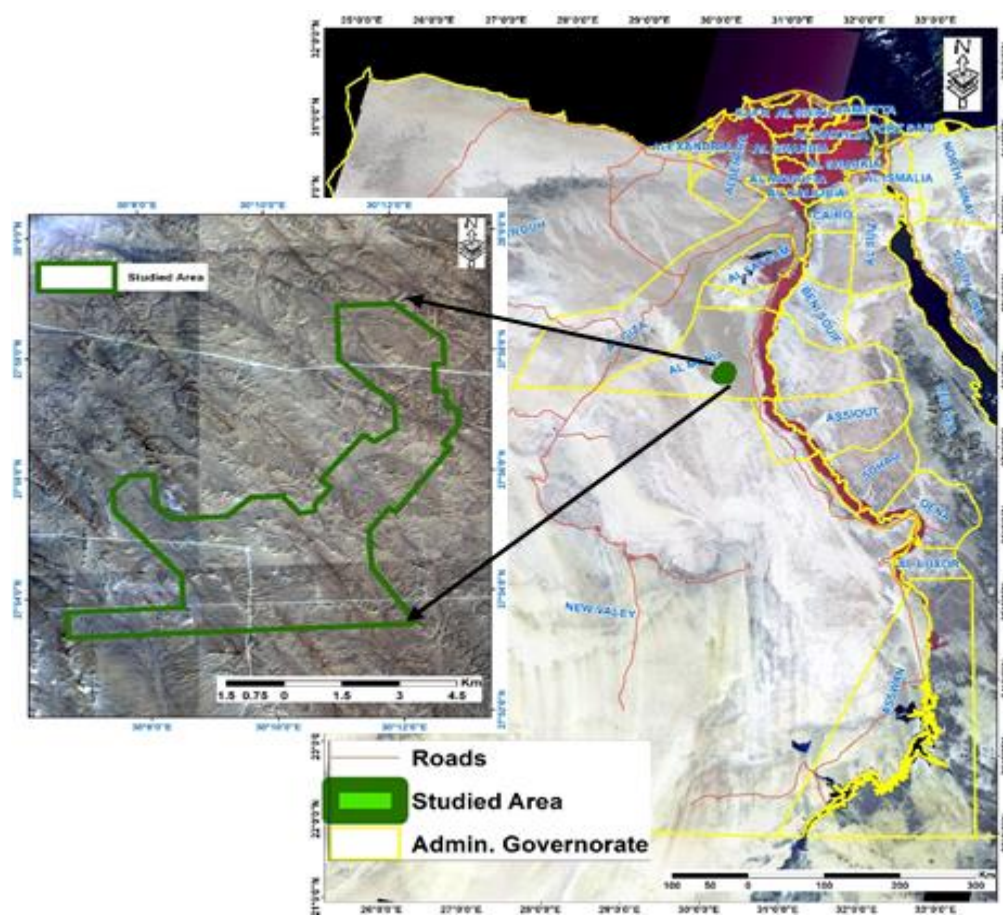
Figure 1:-Location map of the studied area.

Climate

As shown in Table1 the lowest value of rain (0.0) was in June, July and August while the highest value (3.43) in February. The maximum degree (38.77) was in July while the minimum degree (18.88) was in January. The lowest value of relative humidity (24.81%) was in May while the highest value (58.96%) in December. While The lowest value of wind speed (2.07 m/s) was in November while the highest value (3.61 m/s) in August.

**Table 1:-**Climatic characteristics of the study area (CLAC, 2018)

	Rain mm/ day	Wind m/S	RH*	Temperature C			SRAD*
				Mean	Max	Min	
January	1.04	2.49	58.28	12.09	18.88	5.31	15.75
February	3.43	2.16	42.54	17.18	24.38	9.97	13.37
March	0.23	2.54	28.72	20.91	29.57	12.24	21.90
April	0.04	2.99	27.41	23.44	31.88	15.00	24.48
May	0.23	3.43	24.81	28.99	37.25	20.73	26.96
June	0.00	3.48	25.07	30.69	38.57	22.80	29.44
July	0.00	3.36	28.57	31.09	38.77	23.41	29.14
August	0.00	3.61	33.06	31.01	38.47	23.55	27.30
September	0.05	3.55	37.78	28.25	35.37	21.13	23.43
October	0.25	2.95	40.40	24.82	31.69	17.95	19.63
November	1.96	2.07	46.40	19.30	25.90	12.70	12.71
December	1.29	2.44	58.96	13.70	19.87	7.52	14.10
Average and Sum	**8.52**	**2.92**	**37.67**	**23.45**	**30.88**	**16.03**	**21.52**

RH: Relative Humidity (%)   **SRAD**: Solar Radiation (MJ/m^2/day)

Geology:
According to the geological map, produced by EGSA (1988) Moghra Formation is the main formation which represents an area of about (74.9 %) of the total studied area, covering the southern part, Gravely Platform Formation representing an area of (25.1 %) of the total studied area, which concentrated in the northern part of the studied area (Figure 2)
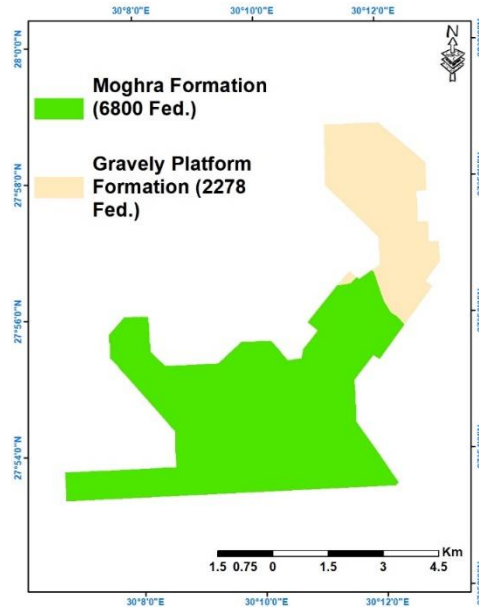
Figure 2:-Geological map of the studied area

Fed. = 4200 m^2

Satellite data:
Data of sentinel 2 dated in August 2019 with spatial resolution of 10 m and spectral resolution of the bands 5, 3 and 2 were used for visual interpretation of the studied area.

Color enhancement operations were used to create new images which is increased the amount of information that can be visually interpreted from the data (Daels, 1986).

Universal Transverse Mercator projection (UTM) were used as main projection of all data and output maps (Daels, 1986).

The geo-statistical analysis techniques were used to create Digital Elevation Model (DEM) using the semi-variogram parameters (Stein, 1998) of contour lines and spot heights.

Field Work:
Seventy-two soil profiles were collected to represent the soils of the studied area. Morphological descriptions of soil profiles were descriped according to FAO, 2006. Soil samples were collected for laboratory analyses.

Nine water samples were collected from the wells in the studied area. Water samples were analyzed to determine some chemical properties according to USDA (2004). These included the electric conductivity (ECe), soluble cations and anions and Sodium Adsorption Ratio (SAR). Suitability of water for irrigation was determine according to the limitations outlined by FAO (1985).

Laboratory Analyses:
The collected soil samples were air dried, crushed and prepared for laboratory analyses, to determine soil chemical and physical properties according to USDA, 2004 methods: particle size distribution, electrical conductivity (ECe) in the soil paste extract, calcium carbonate, gypsum, macronutrients and micronutrients.

Producing thematic maps
The parameters of geo-statistical approach of the surface layer (seventy-two soil samples) were intered using Arc GIS 10.3 to produce soil salinity, soil sodicity, soil lime, soil gypsum, soil texture and soil depth maps. From the semi-variogram operation, it could be possible define which models fitted to the experimental semi-variogram values. The parameters of semi-variogram for best fitting a model were used to interpolate the thematic soil properties based on ordinary Kriging (Stein, 1998).

Land Capability:
Land capability for agriculture was assessed according to the method of Land Capability techniques using the rating tables of FAO (1985), Sys and Verheye (1978) and Sys et al. (1991). The method of land evaluation used according to the following equation:

$$Ci = \frac{t}{100} \times \frac{x}{100} \times \frac{d}{100} \times \frac{l}{100} \times \frac{g}{100} \times \frac{n}{100} \times 100$$

Where:
Ci = Capability index (%), t = Slope, x = Texture, d = Soil depth, l = Lime, g = Gypsum and n = Salinity and alkalinity

Producing fertility maps
According to geo-statistical analyses (Stein, 1998) the mas for macronutrients and micronutrients were produced using the classes in Table 2

Table 2:-The classes of macronutrients and micronutrients

Class	Low	Medium	High
Available Nitrogen (mg kg^{-1})	<40	40-80	>80
Available Phosphorus (mg kg^{-1})	<5	5-10	>10
Available Potassium (mg kg^{-1})	<200	200-400	>400
Available Iron (mg kg^{-1})	< 4.5	4.5 - 9	> 9
Available Manganese (mg kg^{-1})	<2	2-5	>5
Available Zinc (mg kg^{-1})	<1	1-2	>2
Available Copper (mg kg^{-1})	<0.5	0.5-1	>1

The levels of macronutrients outlined by Page *et al.*, (1982) and modified to suit the prevailing conditions in soils of Egypt as mentioned by Baker *et al*. (1999), The range of micronutrients Lindsay and Norvell, (1978) and Baker *et al*., (1999).

Results and discussion:-
**digital elevation model (dem)**
Figure 3 shows the height areas located in the middle side and the elevation ranged from 139 to 159 meter above sea level. The low areas located in the northern and western areas for the studied area as the elevation ranged between 120 and 133 meter above sea level.
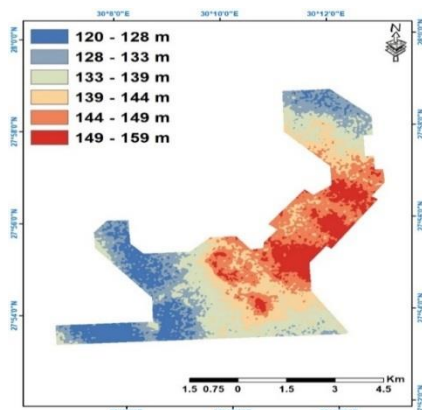
Figure 3:-Digital Elevation Model (DEM) of the studied area

Physiographic soil map of the studied area
Based on sentinel-2 image taken during August 2019, digital elevation model (DEM), the topography and field check, the physiography of the studied area has been identified (Table 3). The obtained data in (Table 3) showed that the representative soil profiles vary in their characteristics mainly due to they have been developed on different landscape – land form- Relief , i.e. alluvial plain, and terraces (Figure 4) as shown in the following discussion.
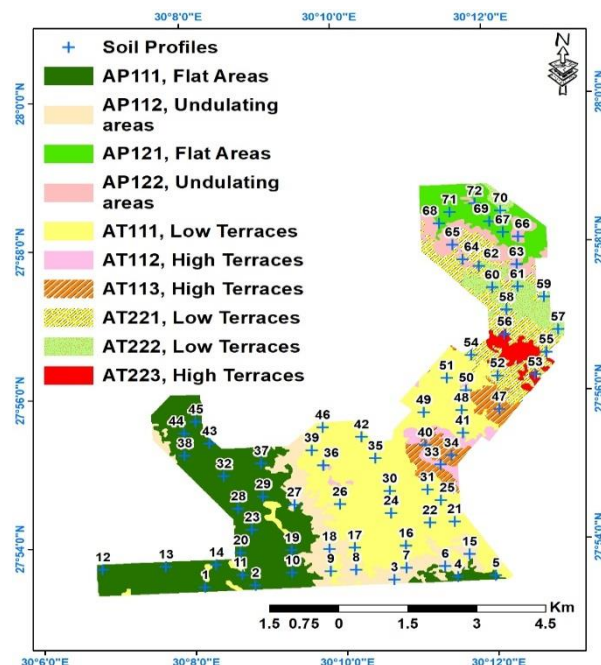
Figure 4:-Location of soil profiles on Physiographic soil map of the studied area

Table 3:-Physiographic soil map legend

Landscape	Relief	Lithology	Landform	Code	Area Feddans	%
Alluvial Plain	Almost Flat	Moghra Formation	Flat Areas	AP111	2389	26.32
	Undulating Areas		Undulating areas	AP112	854	9.41
	Almost Flat	Gravely Platform Formation	Flat Areas	AP121	551	6.07
	Undulating Areas		Undulating areas	AP122	386	4.25
Terraces	Gentaly Undulating Areas	Moghra Formation	Low Terraces	AT111	2945	32.45
			High Terraces	AT112	184	2.02
	Undulating Areas		High Terraces	AT113	393	4.33
	Gently Undulating Areas	Gravely Platform Formation	Low Terraces	AT221	796	8.76
	Undulating Areas		Low Terraces	AT222	392	4.31
			High Terraces	AT223	188	2.08
Total					9078	100

AP111 unit
This soil is almost flat belong to alluvial plain and represented by 20 soil profiles Nos. 1, 2, 4, 5, 10, 11, 12, 13, 14, 19, 20, 23, 28, 29, 32, 37,38, 43, 44 and 45. The soil texture is Sandy Loam, $CaCO_3$ between 2.62 and 23.2 %. EC value in dS m^{-1} ranged from 1.3 to 15.9 and ESP from 3.3 to 18.6 (Table 4). Soil gypsum content vary between 1.1 and 14.2 %.

Table 4:-some chemical, physical and fertility properties of the studied soil profiles for surface layer

No	Depth (cm)	EC dS m⁻¹	Texture*	CaCO₃ %	Gyp. %	ESP	N **	P **	K **	Fe **	Mn **	Zn **	Cu **
1	120	11.8	SL	16.4	12.6	18.6	78	0.07	185.1	11.26	1.5	0.85	0.096
2	120	15.9	SL	8.8	5.7	9.5	78	0.82	139.4	11.31	1.54	0.79	0.098
3	120	3.4	LS	4.4	5.6	7.3	74	0.31	121.6	11.59	1.53	0.7	0.097
4	100	1.4	LS	2.6	1.1	5	56	0.26	53.6	11.48	1.53	0.9	0.097
5	120	11.5	SL	15.3	10	17.2	49	3.49	45.6	0.77	0.17	0.01	0.003
6	120	3.2	LS	5.5	3.2	7.2	56	1.78	232.1	3.31	0.9	0.19	0.004
7	120	8.9	LS	8.4	7.3	17.1	35	1.48	61.8	2.27	0.94	0.08	0.003
8	75	2.7	LS	8.8	5.3	7.1	33	1.28	37.8	2.29	0.96	0.01	0.004
9	70	2.9	LS	14	5.1	7.1	63	1.87	117.2	2.27	0.99	0.01	0.002
10	140	4.5	SL	13.1	6.7	3.3	63	1.57	95.4	2.35	0.99	0.05	0.002
11	55	3.3	SL	5.5	14.2	6.5	63	1.23	74.2	2.41	1.02	0.09	0.002
12	120	2.8	SL	14.3	6	10.3	53	1.78	63	2.47	1.03	0.01	0.002
13	140	12.9	SL	13.9	5.5	18.6	64	1.6	70	2.53	1.07	0.01	0.002
14	60	6.1	SL	7	5.4	5.1	60	1.72	70	2.52	1.1	0.01	0.002
15	120	11.8	SL	8.1	7.2	27.6	66.8	0.59	70	2.57	1.15	0.08	0.002
16	110	3.4	SL	15.8	5.3	7.7	57.6	0.67	49	3.32	1.19	0.09	0.004
17	80	2.3	SL	16.5	8.4	6.9	62	0.56	56	3.84	1.2	0.19	0.004
18	110	10.8	SL	11.4	6.2	12.6	43	0.48	56	3.55	1.22	0.03	0.002
19	140	13.6	SL	4.4	2.3	13.7	78.3	0.07	63	4.41	1.23	0.31	0.004
20	120	5.9	SL	9.6	5.3	4.6	71	0.86	63	3.66	1.53	0.17	0.002
21	120	3.7	SL	11.3	6.2	8.7	42	0.79	78.3	3.67	1.55	0.1	0.002
22	125	0.3	SL	6.3	1.5	3	49	0.44	171.2	3.69	1.46	0.12	0.004
23	120	3.8	SL	7.5	9.9	8.8	49	0.34	148.4	4.13	1.69	0.15	0.003
24	110	0.6	SL	9.4	7.5	4.4	49	0.51	126	5.37	1.71	0.25	0.061
25	85	6.7	SL	10.9	6.1	4.5	42	0.63	194.3	8.66	1.57	0.01	0.003
26	110	8.8	SL	15.2	7.4	6.6	56	0.78	232.1	5.24	1.61	0.01	0.004
27	100	11.6	SL	10.5	7.9	17	49	0.52	70	12.35	1.9	0.01	0.002
28	120	4.1	SL	13.3	11.3	9.2	71	0.42	61.8	6.73	1.79	0.01	0.003
29	120	4	SL	13.3	7.9	9.1	78	0.48	232.1	5.38	1.83	0.1	0.002
30	120	10.2	LS	4.7	3.6	6.6	71	0.68	112.8	5.43	1.97	0.19	0.002
31	120	2.8	SL	11.3	6	7.4	63	0.53	45.6	8.13	1.9	0.01	0.004
32	125	10.7	SL	10.3	5.9	14.8	78	0.18	213.1	7.04	1.9	0.01	0.002
33	90	3.6	SL	18.4	14.3	5.2	63	0.12	315	1.28	0.06	0.17	0.004
34	70	9.7	SL	16.9	14.3	6.3	70	0.11	407.4	0.51	0.17	0.06	0.002
35	120	1.7	SL	10	8.9	4	70	0.07	342.4	0.5	0.13	0.01	0.002
36	110	2.5	SL	14.1	6.5	6.1	56	0.44	173.6	1.49	0.25	0.14	0.003
37	120	6.4	SL	7.3	8.2	9.5	56	0.64	99.2	1.13	0.18	0.16	0.003
38	80	11.5	SL	10.3	11.8	15.8	28	0.41	360.9	1.58	0.28	0.01	0.003
39	110	2.5	SL	11.4	6.2	4	42	0.17	252	0.94	0.21	0.01	0.004
40	115	6.3	SL	10.4	8.2	3.7	49	0.06	296.8	1.91	0.13	0.14	0.003
41	110	15.9	SL	16.1	8.4	8.2	56	0.1	315	0.92	0.18	0.01	0.003
42	100	12.3	SL	10.9	6.2	6.3	63	0.12	225.5	0.47	0.1	0.03	0.004
43	75	4.9	SL	23.2	10.9	10	49	0.74	28.2	2.41	0.62	0.27	0.004
44	100	9.4	SL	13.4	7	13.4	70	0.21	315	0.92	0.17	0.1	0.003
45	100	3.3	SL	18.3	10.3	8.3	35	0.17	333.2	0.49	0.15	0.26	0.004
46	110	6.6	SL	14.3	10.2	4	35	0.6	199.4	1.35	0.28	0.22	0.003
47	90	11.9	SL	12.3	7	19.5	21	0.12	225.5	1.23	0.31	0.15	0.002
48	90	10.8	SL	12.3	5	10.4	31.5	0.36	260.9	1.19	0.34	0.23	0.002
49	100	9.1	SL	12.3	5	23	63	0.36	173.6	1.89	0.43	0.18	0.004
50	100	5.3	LS	12.7	6.3	6.5	56	0.77	83.4	2.2	0.62	0.14	0.003
51	90	13.8	SL	13.1	5.5	8.7	56	0.34	123.5	1.21	0.59	0.15	0.003

Table 4 Cont.

No	Depth (cm)	EC dS m^{-1}	Texture*	CaCO$_3$ %	Gyp. %	ESP	N **	P **	K **	Fe **	Mn **	Zn **	Cu **
52	100	7.3	LS	12.8	9.3	12	56	0.09	216.8	6.95	0.41	0.25	0.004
53	90	3	SL	11.5	7.4	8	56	0.6	416.8	1.87	0.51	0.23	0.006
54	65	3.5	LS	19	5.5	8.6	49	0.6	190.8	3.4	1.83	0.23	0.004
55	90	5.7	LS	13.5	7.2	10.7	56	0.13	287.8	2.89	0.57	0.18	0.004
56	60	11.8	SL	10.3	8.8	15.6	65	0.2	360.8	2.64	0.55	0.29	0.003
57	60	3.3	LS	14.6	11	7	79	0.72	234.3	2.59	0.73	0.38	0.002
58	75	3.7	SL	11	10.9	7.4	49	0.75	75.6	1.31	0.74	0.24	0.002
59	130	0.5	SL	8.4	3.4	3.1	49	0.76	107.2	1.42	0.67	0.35	0.004
60	140	0.7	SL	5	6.2	3.6	49	0.48	360.8	1.59	0.68	0.38	0.004
61	140	0.4	SL	6	8.4	4	49	0.65	287.8	2.52	0.69	0.41	0.003
62	140	0.7	SL	10	5.5	3.3	49	1.28	252	1.58	0.66	0.28	0.185
63	130	0.6	SL	8.3	4.5	3.9	56	0.41	342.4	1.49	0.97	0.35	0.006
64	60	0.3	LS	10.7	7.5	3.4	63	1.43	140	1.52	0.73	0.38	0.006
65	140	1.9	LS	4.4	5.3	4	49	0.71	165.2	3.34	0.76	0.35	0.003
66	140	1	SL	9.4	5.5	3.8	42	1	140	1.01	0.75	0.26	0.006
67	85	4.4	SL	14	13.5	8	70	0.48	315	1.11	0.76	0.17	0.002
68	90	1.7	LS	13.1	9.2	3.4	56	0.32	269.8	4.89	0.9	0.18	0.004
69	120	2.1	LS	9.6	7.5	2.6	63	0.66	216.8	7.99	1.19	0.3	0.002
70	90	2.9	SL	10.1	8.4	3.8	56	0.85	156.7	1.74	0.89	0.3	0.002
71	95	9.9	LS	11.4	6.6	9.2	63	0.62	173.6	3.25	1.01	0.24	0.006
72	110	2.8	LS	14	5.6	12.9	70	0.7	243.1	1.14	0.92	0.13	0.002

* SL: Sandy Loam   LS: Loamy Sand   Gyp.: Gypsum   ESP: Exchangeable Sodium percentage
** macro and micro nutrients in mg kg $^{-1}$

AP112 unit
This soil is undulating topography belong to alluvial plain landscape and represented by 7 soil profiles Nos. 3, 6, 7, 8, 15, 18 and 27 .The soil texture vary between Loamy Sand and Sandy Loam, CaCO$_3$ between 4.3 and 11.3 %. EC value in dS m^{-1} ranged from 2.6 to 11.8 and ESP from 7.0 to 27.6 (Table 4). Soil gypsum content vary between 3.2 and 7.9%.

AP121 unit
This unit is Almost Flat topography belong to alluvial plain and represented by 4 soil profiles Nos. 67, 68, 69 and 71 .The soil texture vary between Loamy Sand and Sandy Loam, CaCO$_3$ between 9.6 and 14 %. EC value in dS m^{-1} ranged from 1.7 to 9.8 and ESP from 2.6 to 9.2 (Table 4). Soil gypsum content vary between 6.6 and 13.5 %.

AP122 unit
These soils are undulating topography belong to alluvial plain and represented by 5 soil profiles Nos. 63, 64, 65, 66, and 72 .The soil texture vary between Loamy Sand and Sandy Loam, CaCO$_3$ between 4.3 and 14 %. EC value in dS m^{-1} ranged from 0.3 to 2.8 and ESP from 3.4 to 12.9 (Table 4). Soil gypsum content vary between 4.5 and 7.5 %.

AT111 unit
These soils are gently undulating topography belong to terraces landscape and represented by 18 soil profiles Nos. 9, 16, 17, 21, 22, 24, 25, 26, 30, 31, 35, 39, 41, 42, 46, 48, 49 and 51 .The soil texture vary between Loamy Sand and Sandy Loam, CaCO$_3$ between 4.7 and 16.5 %. EC value in dS m^{-1} ranged from 0.3 to 15.9 and ESP from 3 to 23 (Table 4). Soil gypsum content vary between 1.5 and 10.2 %.

AT112 unit
This unit is gently undulating topography belong to terraces landscape and represented by 3 soil profiles Nos. 33, 36 and 50 .The soil texture vary between Loamy Sand and Sandy Loam, CaCO$_3$ between 12.7 and 18.4 %. EC value in dS m^{-1} ranged from 2.5 to 5.3 and ESP from 5.2 to 6.5 (Table 4). Soil gypsum content vary between 6.3 and 14.3 %.

AT113 unit
This unit is undulating topography belong to terraces landscape and represented by 3 soil profiles Nos. 34, 40 and 47 .The soil texture is Sandy Loam, $CaCO_3$ between 10.4 and 16.9 %. EC value in dS m^{-1} ranged from 6.3 to 11.9 and ESP from 3.7 to 19.5 (Table 4). Soil gypsum content vary between 7.0 and 14.3 %.

AT221 unit
This unit is gently undulating topography belong to terraces landscape and represented by 4 soil profiles Nos. 52, 54, 55 and 62 .The soil texture vary between Loamy Sand and Sandy Loam, $CaCO_3$ between 10.0 and 19.0 %. EC value in dS m^{-1} ranged from 0.7 to 7.3 and ESP from 3.3 to 12 (Table 4). Soil gypsum content vary between 5.5 and 9.3 %.

AT222 unit
This unit is undulating topography belong to terraces landscape and represented by 6 soil profiles Nos. 57, 58, 59, 60, 61 and 70 .The soil texture vary between Loamy Sand and Sandy Loam, $CaCO_3$ between 5.0 and 14.6 %. EC value in dS m^{-1} ranged from 0.4 to 3.7 and ESP from 3.1 to 7.4 (Table 4). Soil gypsum content vary between 3.3 and 11. %.

AT223 unit
These soils are undulating topography belong to terraces landscape and represented by 2 soil profiles Nos. 53 and 56 .The soil texture is Sandy Loam, $CaCO_3$ between 10.3 and 11.5 %. EC value in dS m^{-1} ranged from 3.0 to 11.8 and ESP from 8 to 15.6 (Table 4). Soil gypsum content vary between 7.4 and 8.8 %.

Producing thematic maps of the studied area:
Soil depth map
The total depth of soil profiles were between 55 and 140 cm with mean 105 and the standard deviation is 22.89. Figure 5 indicated that the soils of very deep whereas depth more than 120 cm cover about 1415 Feddans (15.59 % of the total studied area . The deep soils represented an area of about 4163 Feddans (45.86 % of the total studied area) where as depth is between 100 and 120 cm. the soils of moderately deep were about 3500 Feddans (38.55 %% of the total studied area) with depth from 50 to 100 cm.
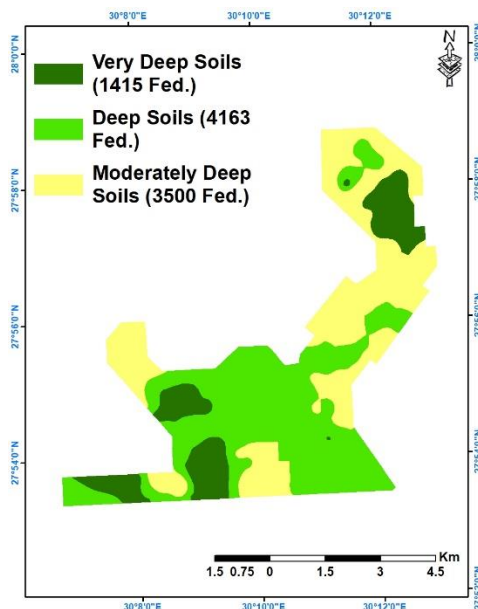
Figure 5:-Soil depth map of the studied area.

Soil texture map
Figure 6 indicated the dominant soil texture is Sandy Loam that representing an area about 6822 Feddans (75.15 % of the total studied area). On other hand the soils of Loamy Sand were 2256 Feddans (24.85 % of the total studied area).
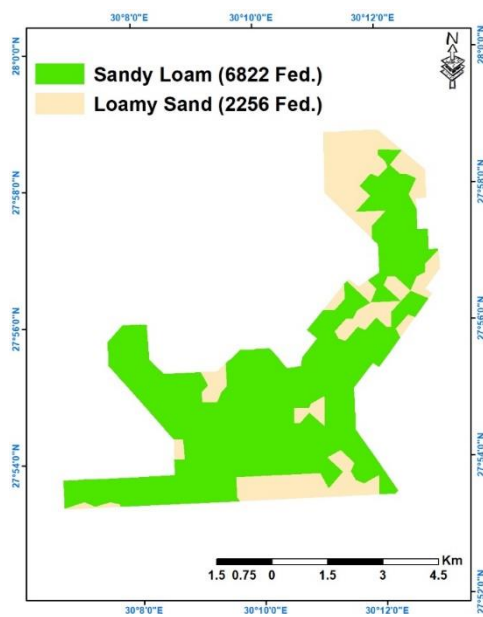
Figure 6:-Soil texture map of the studied area.

Soil salinity map

Using geo-statistical approach for 72 soil samples for surface layer. ECe values ranged from 0.3 to 15.9 dS m^{-1} within mean of 5.85. The standard deviation is 4.3 %. As indicated in Figure 7 and Table 4 the soils of slightly saline (ECe less than 4) cover an area of about 27.97 % of the total studied area. The soils of moderately saline soils (ECe 4 - 8) representing an area of about 38.82 % of the total studied area. The highly saline soils (ECe 8 - 16) 33.21% of the total studied area.
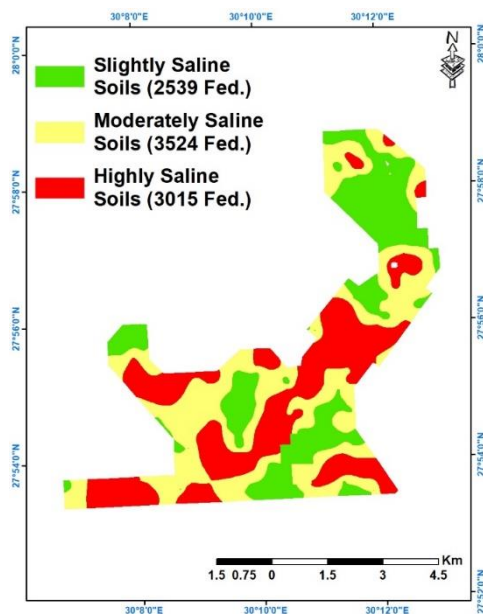
Figure 7:-Soil salinity map of the studied area.

Soil sodicity map

Exchangeable Sodium Percentage (ESP) ranged between 2.55 and 27.6 for surface layers within mean of 8.66 and the standard deviation is 5.16 %. Figure 8 and Table 4 indicated that the soils of non sodic whereas ESP less than 15

cover about 92.72 % of the total studied area. The soils of sodic-affected areas as ESP more than 15 cover about 7.28 % of the total studied area.
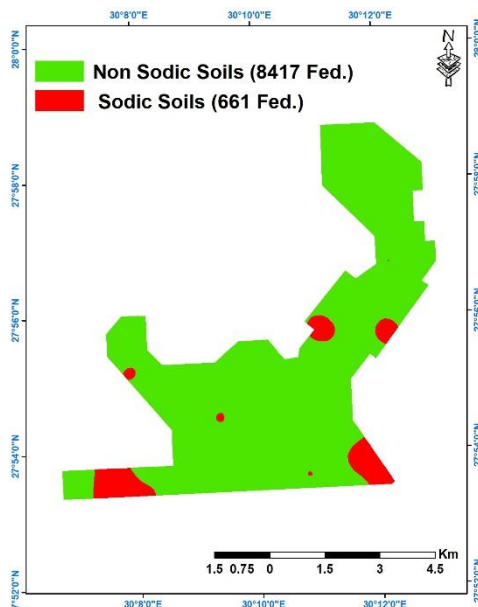
Figure 8:-Soil sodicity map of the studied area.

Soil lime map
Calcium carbonate was between 2.62 % and 23.2% with mean 11.28% and the standard deviation is 11.28%. Figure 9 indicated that the soils of moderately calcareous whereas $CaCO_3$ ranged from 2 to 10 % cover about 29.34 % (2664 Feddans) of the total studied area. The soils of strongly calcareous represented an area of about (6414) Feddans (70.66 % of the total studied area) where as $CaCO_3$ is between 10 and 25 %.
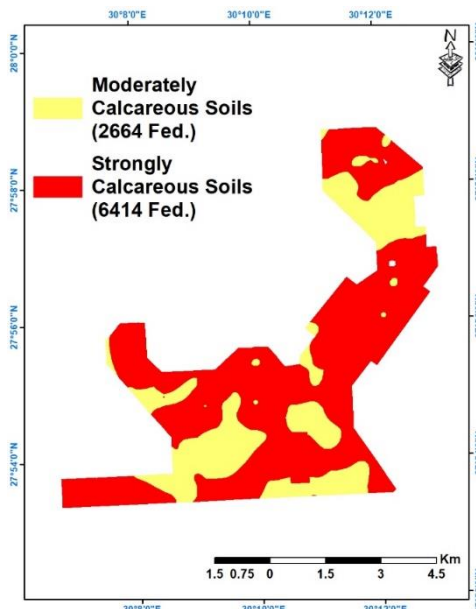
Figure 9:-Soil lime map of the studied area.

Soil gypsum map
Soil gypsum content was between 1.1 and 14.3 % with mean 7.32 % and the standard deviation is 2.8 %. Figure 10 indicated that the soils of Slightly gypsiric whereas gypsum content less than 5 % cover about 5.88 % of the total studied area (533 Feddans). The soils of moderately gypsiric represented an area of about 8545 Feddan (94.12 % of the total studied area) where as gypsum content is between 5 and 15 %.
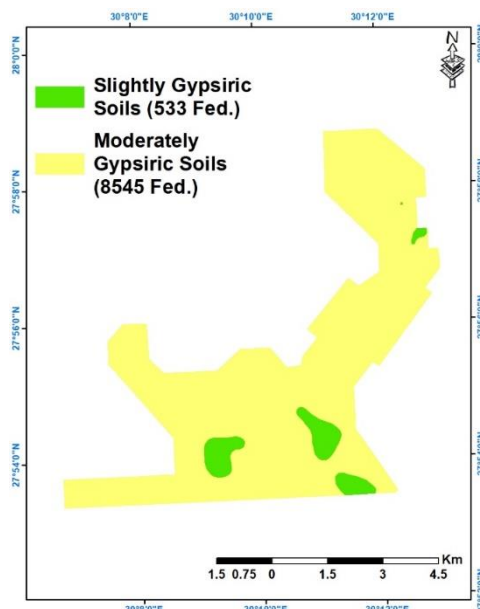
Figure 10:-Soil gypsum map of the studied area.

Land Capability for agriculture
Current land capability
Current land capability refers to the capability for a defined land in its present condition without major improvement (FAO, 1976). It may refer to the present use of land, either with existing or improved management practices, or to a different use. The current capability of the studied area is estimated by the present land characteristics and their ratings outlined by Sys et al. (1991). Figure (11) shows a detailed description of the current land capability subclasses in the studied area
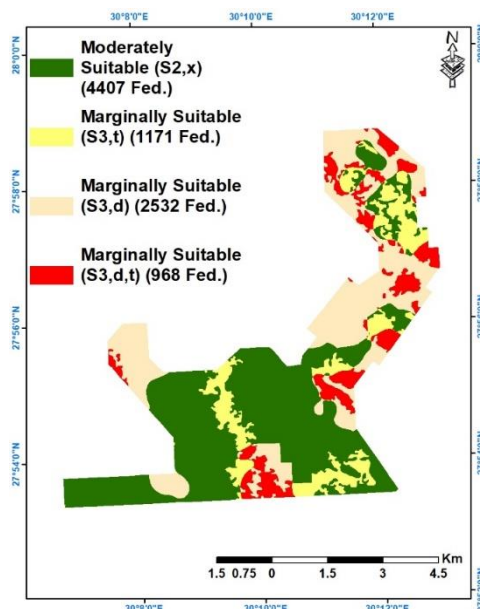
Figure 11:-Current land capability map of the studied area.

Using ARC GIS to overlay all factors i.e. depth, texture, topography, salinity, sodicity, and lime (calcium carbonate) to produce land capability map (Figure 8). One order (S) and four subclasses (S_2x, S_3t, S_3d and S_3d, t) were recognize in the studied soils, the current capability classes is given as follows.

1. **S₂x**: This class occupies an area of about 4407 Feddans, representing 48.55 % of studied area; this subclass representing soils of very deep and deep classes. The soils are flat topography with texture is the only limiting factor.
2. **S₃t**: This subclass occupies an area about 1171 Feddans and representing 12.89 % of total area. The soils are very deep and deep while the most limiting factor is topography (undulating topography**).**
3. **S₃d**: The soils are moderately deep that representing an area of about 2532 Feddans (27.89 % of total area). The depth is the most limiting factor. The recommended cultivated crops are medical and aromatic crops, in addition to fodder crops.

4. **S₃d,t**: The soils are moderately deep and have undulating topography with an area 968 Feddans (10.66 % of total area). The depth and topography are the most limiting factor.

Potential land capability
for this propose, the land utilization is applicable after executing specified major land improvements as proposed in the current study according to their necessity. In The studied area, land improvements is required to management the severity of limitations exiting in the area under consideration such as; Leveling of undulating surfaces of high and low land area, modern irrigation systems such as drip and sprinkler to save irrigation water and prevent rise of ground water table. Add organic fertilizers, green manures and soil conditioners to increase soil fertility and improve the physical and chemical soil properties.

Potential land capability of studied soils as shown in Figure (12) indicated the existing of one order (S), two subclasses (S_2x and S_3d) as follows:
1. S_2x: This capability subclass covers an area about 5578 Feddans represents 61.45 % of total area (Figure 12).
2. S_3d: It is covers 3500 Feddans and 38.55 % of total study area. Whereas the depth is the most limiting factor.
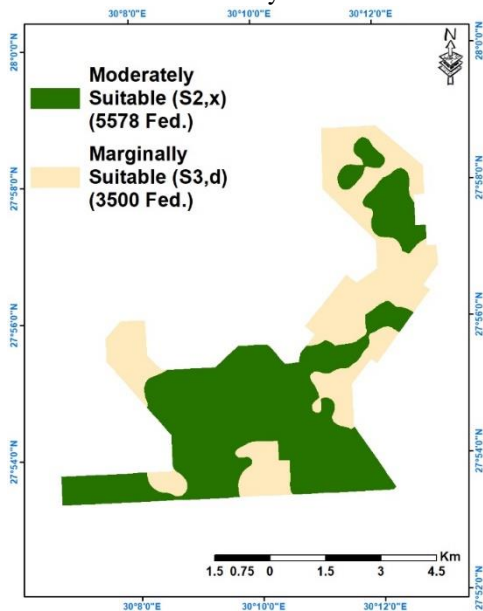
Figure 12:-Potential land capability map of the studied area.

Producing fertility maps of the studied area:
Available Nitrogen
The data in Table 4 reveals the available nitrogen content was between 21 and 79 mg kg $^{-1}$ with mean 56.4 and the standard deviation is 12.77. Figure 13 revealed that the soil of low nitrogen was the smallest area (222 Feddans, 2.45 % of the total studied area). While the soils of medium were the large class (8856 Feddans, 97.55 % of the total studied area).
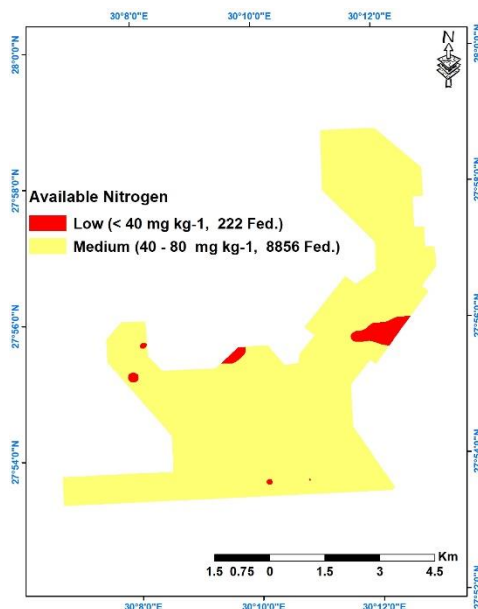
Figure 13:-Soil available nitrogen content

Available Phosphorous

All values for available phosphorous were less than 5 mg kg $^{-1}$ (Table 4), so all soils is one class (low). Available phosphorous ranged between 0.05 and 3.49 mg kg -1 with mean 0.66 and the standard deviation is 0.56.

Available Potassium

The data in Table 4 reveals the available potassium content was between 28.2 and 416.8 mg kg $^{-1}$ with mean 179.06 and the standard deviation is 104.53. Figure 14 revealed that the soil of low potassium class (6128 Feddans, 67.5 % of the total studied area). While the soils of medium class were (2932 Feddans, 32.3 % of the total studied area). The high class potassium was (18 Feddans, 0.2 % of the total studied area).
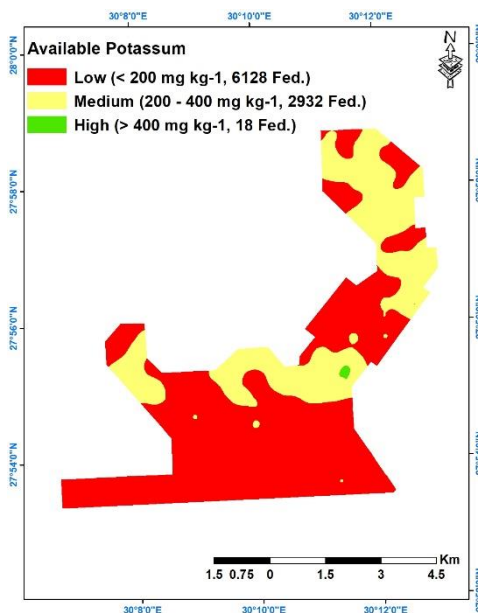

Figure 14:-Soil available potassium content

Available Iron

Table 4 indicated that the content of available iron was between 0.47 and 12.35 mg kg $^{-1}$ with mean 3.41 and the standard deviation is 2.93. Figure 15 revealed that the soil of low iron class (6768 Feddans, 74.56 % of the total

studied area). While the soils of medium class was (2223 Feddans, 24.48 % of the total studied area). The high class iron was (87 Feddans, 0.96 % of the total studied area).
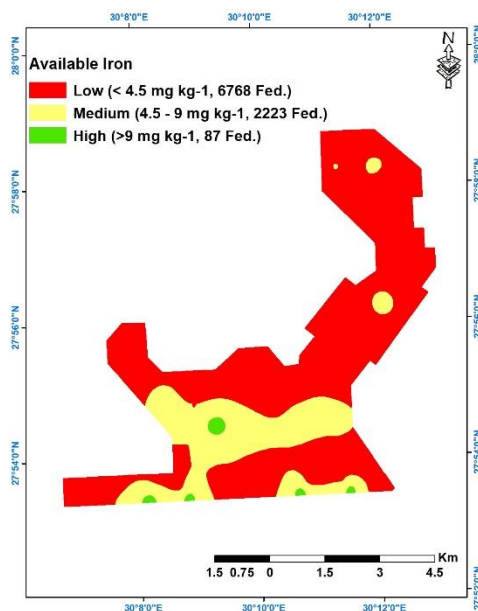

Figure 15:-Soil available iron content

Available Manganese
The data in Table 4 reveals the available manganese content for all values less than 2 mg kg $^{-1}$ so all soils are low class. Available manganese ranged between 0.05 and 1.97 mg kg $^{-1}$ with mean 0.91 and the standard deviation is 0.55.

Available Zinc
The data in Table 4 showed the available zinc content for all values less than 1mg kg $^{-1}$ so all soils are low class. Available zinc ranged between 0.006 and 0.9 mg kg $^{-1}$ with mean 0.19 and the standard deviation is 0.18.

Available Copper
The data in Table 4 indicated the available copper content for all values less than 0.5 mg kg $^{-1}$ so all soils are low class. Available copper ranged between 0.002 and 0.18 mg kg $^{-1}$ with mean 0.011 and the standard deviation is 0.03.

Water quality for irrigation
The ground water is the only source for irrigation. The chemical analysis was done to detect the degree of water quality for irrigation (FAO, 1985) as follows:

TDS (mg l^{-1})	**Water quality**
0-600	Suitable for irrigation
600-1100	Moderately suitable for irrigation
1100-2100	Low suitable for irrigation
More than 2100	Not suitable for irrigation unless for highly tolerant salinity crops

The water quality for water samples from 9 wells were classified as (C3- S1) class (high salinity and low alkalinity) for all water samples except for samples Nos. 4 and 8 is (C2- S1) (moderately salinity and low alkalinity). On other hand water sample No. 7 is (C4- S1) (very highly saline and low sodium water) not suitable for irrigation purposes where it contains more than 2100 mg l^{-1} salts (Table 5).

Table 5:-Chemical properties of irrigation water of some selected wells in the studied area

Sample No.	1	2	3	4	5	6	7	8	9
pH	7.6	7.6	7.3	7.2	7.4	7.2	7.35	7.6	7.6
EC (dS cm^{-1})	2.32	2.32	2.47	1.66	2.36	1.78	3.71	1.59	2.33
TDS (mg l^{-1})	1486	1486	1582	1062	1508	1126	2372	1015	1494
SAR	4.32	4.32	4.65	3.65	4.61	3.6	5.58	3.15	4.42
HCO$_3$ (mg l^{-1})	80.52	80.52	80.52	80.52	86.62	80.52	109.19	103.7	109.2
CO$_3$ (mg l^{-1})	-	-	-	-	-	-	-	-	-
Cl (mg l^{-1})	373.1	373.2	414.99	330.86	409.31	318.79	691.9	318.8	493.5
NO$_3$ (mg l^{-1})	0.11	0.04	0.05	10.36	2.59	10.29	6.31	-	-
PO$_4$ (mg l^{-1})	1.5	1.5	1.5	0	0.85		-	-	-
SO$_4$ (mg l^{-1})	505.4	505.4	524.16	345.6	485.76	374.4	693.6	306.72	459.4
NH$_4$ (mg l^{-1})	0.07	0.11	0.11	1.68	0	0.07	2.55	-	-
Na$^+$ (mg l^{-1})	240.12	240.12	264.27	184	256.22	8	390.1	161	264.3
K$^+$ (mg l^{-1})	8.95	8.59	8.99	8.99	8.99	0.23	13.2	7.82	10.16
Ca (mg l^{-1})	90.2	107	118.4	84.6	124	4.97	208.4	62	101.4
Mg (mg l^{-1})	86.16	76.08	75.48	64.68	65.88	5.08	96.24	81.24	101.3
Mn (mg l^{-1})	0.02	0.5	0.5	0.081	0	0.076		-	-
Fe (mg l^{-1})	0.2	0.2	0.2	0.161	0	0.084	0.021	-	-
Cu (mg l^{-1})	0.2	0.2	0.2	0.049	0	0.043	-	-	-
Zn (mg l^{-1})	0.2	0.2	0.2	0	0	-	-	-	-
B (mg l^{-1})	0.19	0.17	0.17	0.075	0	0.071	0.273	-	-
Mo (mg l^{-1})	-	-	-	-	-	-	-	-	-

The wells Nos. 1, 2, 3 and 4 are located in the soils of current capability S$_2$ x, while the wells Nos. 5 and 6 are located in the soils of current capability S$_3$ t. On other hand, the wells Nos. 7 and 8 are located in the soils of current capability S$_3$ d. Finally, the well No. 9 is located in the soils Current capability S$_3$ d, t

Proposed crops for the studied area
Regarding to soil evaluating and water quality the suitable crops for the studied area are sugar beet, fodder beet, date palm, olive, fig, pomegranate, peach, apricot, barely, wheat, sorghum, maize, cowpea and sunflower. In addition, medical and aromatic crops are suitable for such soils. The recommended irrigation systems are sprinkler, drip or pivot systems.

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