Assessment of Soils of Wadi El-Natrun Area, Egypt Using Remote Sensing and GIS Techniques

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Abstract: The studied area is located between longitudes 30° 06′ 21".37 to 30° 28′ 50".02 East and latitudes 30° 18′ 02".88 to 30° 31′ 06".66 North and covers about 142,687 fed. A physiographic analysis using visual interpretation on Spot 4 of false colour composite of bands 3,2,1 scale 1:50000 was carried out to delineate the different physiographic units of the studied area. Physiographic units were accurate defined by the Digital Elevation Model of Wadi El-Natrun area. Thirty four soil profiles and seventy minipits were examined to represent the soils of the studied area. The physiographic units were incorporated with soil taxonomic units of sub great group level and field data to represent physiographic soil map of the studied area. The soils of the studied area are slightly to extremely saline (EC values range from 1.0 to 71.9 dS/m). Soil texture is mostly sandy to sandy clay loam. Soil pH values range from 7.2 to 8.0. Organic matter content is very low with a maximum value of 0.3%. The soils are classified as Typic Haplocalcids, Vertic Aquisalids, Lithic Aquisalids, Lithic Torriorthents, Typic Torripsamment and Typic Torriorthents. The data reveal that current capability of soils is moderately suitable (S_2), marginally suitable (S_3), temporary not suitable (N_1) and permanently not suitable (N_2). The soils of class S_2 form 44.2% of the studied area (~ 63066 fed.). It includes one subclass S_2x, as the texture is the limiting factor. The soils of class S_3 cover an area of about 69715 fed. (48.9 %) and it contains three subclasses namely S_3xn (texture and salinity are the limiting factors), S_3tx (topography and texture are the limiting factors) and S_3txn (topography, texture and salinity are the limiting factors). The soils of class N_1 form 1.9 % of the studied area (~ 2756 fed.). The soils of class N_2 cover about 5331 fed. (~ 3.8 %). Potential capability reveals that the soils of subclasses S_3 xn, S_3tx and S_3txn could be improved to subclass S_2 x. Five crops were selected to asses their convenience for cultivation in the studied area: wheat, barley, grapes, alfalfa and fodder beet. [Journal of American Science. 2010;6(10):195-206]. (ISSN: 1545-1003).

Keywords: Assessment; Soils; Wadi El-Natrun Area; Egypt; GIS Techniques

1. Introduction

There is no doubt that the ratio between the land resources and human resources is the most critical problem in Egypt. So agriculture expansion in the Western Desert is one of the most vital objectives of the Egyptian policy to meet the food security requirements of the tremendous increase in population.

The national strategy of Egypt for horizontal expansion of agricultural lands until year 2017 aims at adding about 4.3 million feddans in different regions, depending on land suitability and water resources.

Wadi El-Natrun area could be considered as one of the promising areas for agricultural development. Land suitability is essential for the studied area in order to provide the planners with the necessary information they needed. However, sometimes the survey data are difficult to be understood by them. When, the variables are translated into productivity terms, they become more relevant and supporting. Land capability systems are the tools to convert the figures and specialized expression of soil characteristics into meaningful language for decision makers and non specialized users.

Sadek (1993) used Landsat Multispectral Scanners (MSS) and Thematic Mapper data for the potential for agricultural expansion of the west Nile Delta. He found that the land suitability classification of west Nile Delta using FAO, 1976, are marginally suitable land (S_3); these soils include part of Wadi El-Natrun, Wadi El-Ralat, and Wadi El-Fargh terrace with limitations due to texture, moisture deficiencies, low fertility and physical soil deficiencies. According to Ashmawy (2003) and Abdel-Hamid (2008) the most effective parameters that influence the suitability classification in Wadi El-Natrun area are soil texture, topography, salinity and soil depth.

The combination of remote sensing data with geographic information system (GIS) has been used in several fields such as land management, monitoring soil salinity, etc with very good results (Cisse et al., 1984, De Vries, 1985, Abdel-Hamid 1990 and Abdel-Hamid et al., 1992).

The present work aims to evaluate the potentiality of the soils of the studied area. Land evaluation was performed using adapted system to fit the conditions of the area under investigation. Five crops were selected to asses their convenience for cultivation in the studied area. Suitability maps for soil and selected crops are included.

2. Material and Methods

The area under investigation is located between longitudes 30° 06′ 21".37 to 30° 28′ 50".02 East and latitudes 30° 18′ 02".88 to 30° 31′ 06".66 North and covers about 142,687 fed. (Fig. 1). Spot data (Spot 4) scene acquired on July the 31th 2007, (K 110 and J 289) and topographic maps of the area have been used for the visual interpretation (Zinck 1988) and Digital Elevation Model (DEM) (Stein 1998). The interpretation was done on a false colour composite of bands 3, 2 and 1 scale 1:50,000.

Thirty four soil profiles and seventy minipits were collected and subjected for the following analyses: Particle size distribution (Piper, 1950); using the sodium hexametaphosphate for dispersion in calcareous soils (USSL Staff, 1954), calcium carbonate, electric conductivity (ECe) in the soil paste extract, soluble cations and anions, soil pH, organic matter content (Jackson, 1973); cation exchange capacity and exchangeable sodium (Black, 1982).

The results obtained from the visual interpretation and digital elevation model and information from field data was incorporated using GIS (Fig. 2) in order to produce soil map of the studied area.

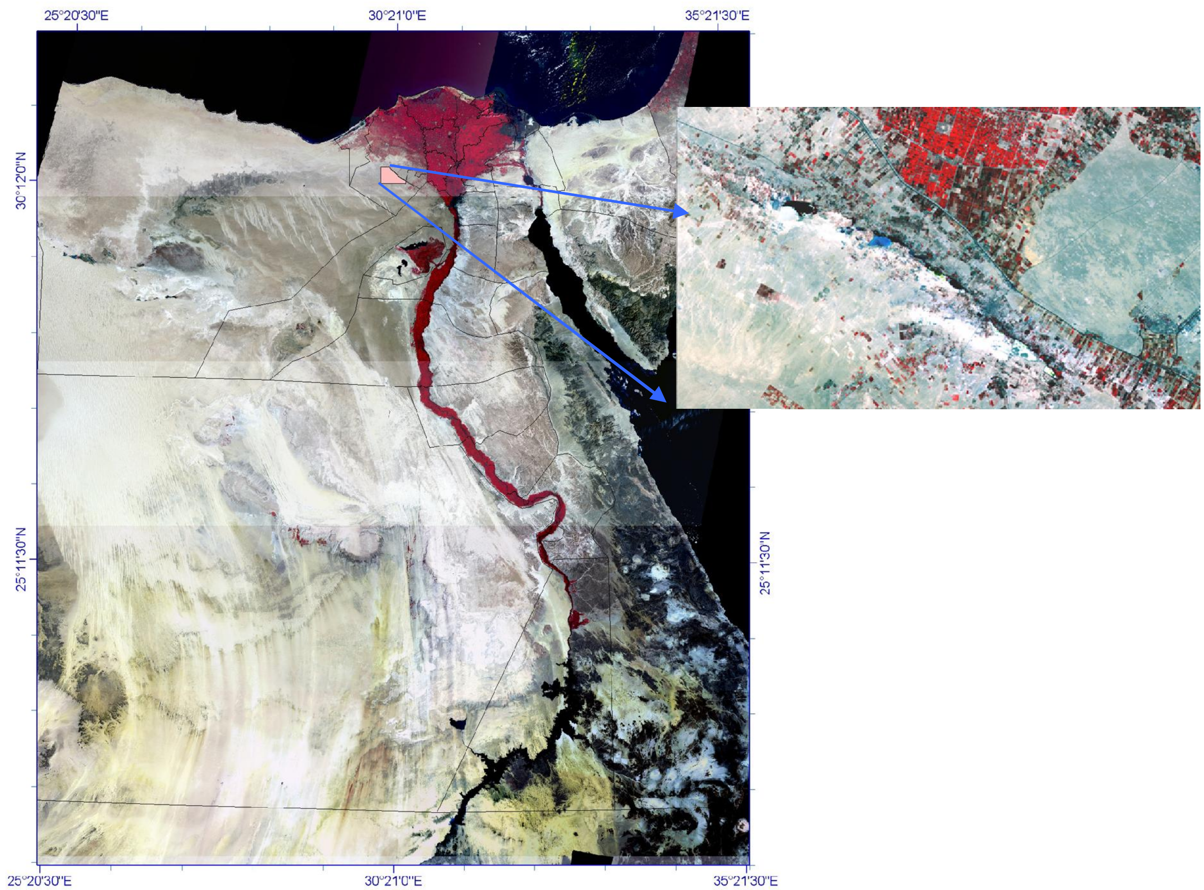

Fig. (1) Location map of the studied area.

Land suitability techniques were done using the rating tables suggested by Sys and Verheye (1978); FAO (1976 and 1983) and Sys (1985, 1991) according to the equation:

$$Ci = t \times \frac{w}{100} \times \frac{s_1}{100} \times \frac{s_2}{100} \times \frac{s_3}{100} \times \frac{n}{100}$$

Where:

Ci = Capability index (%)
t = Slope (t)
w = Drainage conditions (w)
s_1 = Texture (x)
s_2 = Soil depth (d)
s_3 = $CaCO_3$ content (k)
n = Salinity and alkalinity (n)

Five crops were selected to asses their convenience for cultivation in the studied area. The selected crops are: wheat, barley, grapes, alfalfa and fodder beet. Soil characteristics of the different mapping units were compared and matched with the requirements of each crop. The matching led to the current and potential suitability for each land use using the parametric approach and land index mentioned by Sys et al. (1993).

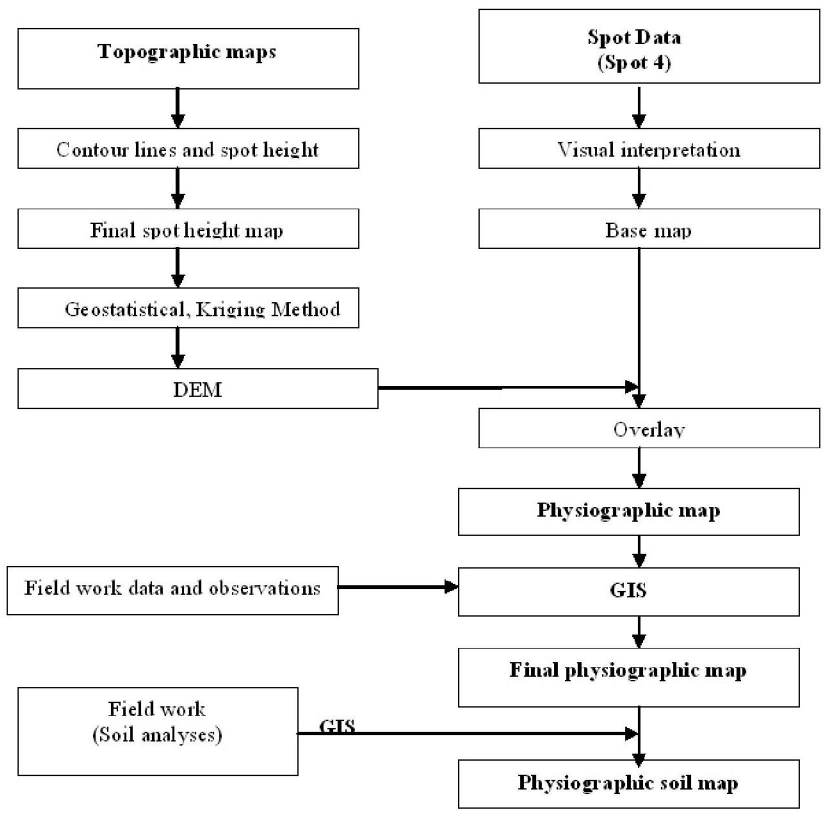

Fig. (2): Flow chart showing various methods used and combination of the results using Geographic Information System (GIS).

3. Results and Discussion

The visual interpretation of the spot (spot4) data and digital elevation model of topographic maps have resulted in a physiographic map of the studied area. Incorporating the physiographic units with Soil Taxonomy and soil field data using Geographic Information System (GIS) resulted in the physiographic soil map (Fig., 3 and Table 1). The soil characteristics of the mapping units are shown in Table (2).

The studied soils are classified according to USDA (2006) as Typic Haplocalcids, Vertic Aquisalids, Lithic Aquisalids, Lithic Torriorthents, Typic Torripsamment and Typic Torriorthents (Table 1).

Current land capability:-

From the agriculture point of view, soils of the studied area are considered as promising soils. Evaluating their capability is an essential stage for future practical use. Current land capability refers to the capability for a defined use of land in its present condition, without major improvement (FAO, 1976).

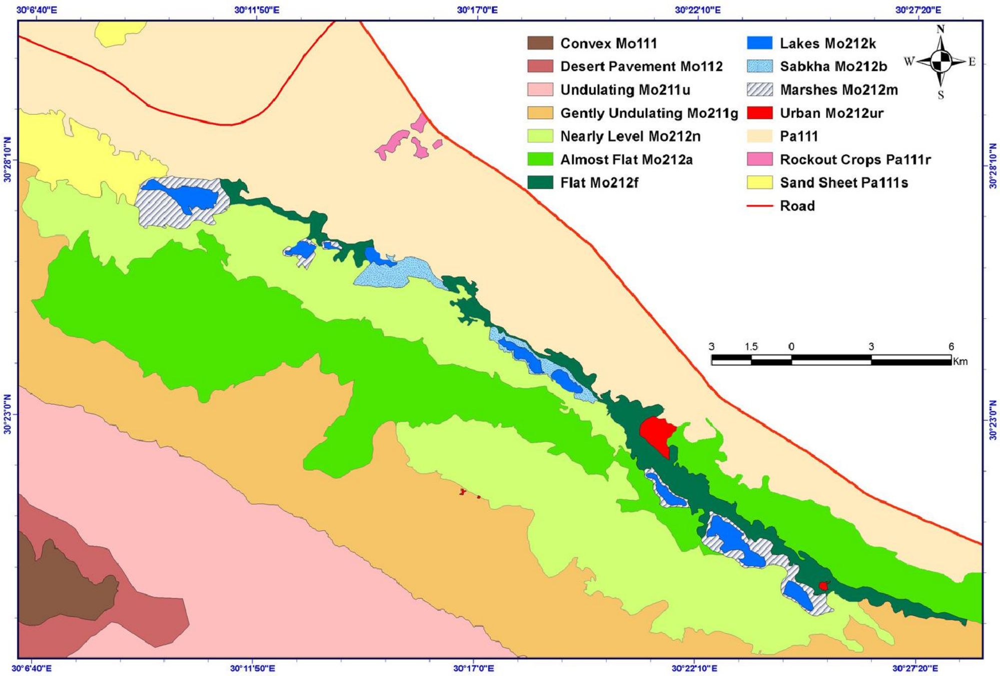

Fig. (3) Physiographic soil map of the studied area.

Table (1) Legend of the physiographic mapping units

Landscape	Relief	Lithology	Landform	Phase	Symbol	Area fed.	Area %	Soil classification	Kind of mapping unit
Mountain (Mo)	Hogback (Mo1)	Sandstone with gravel	Summit	Convex	Mo111	1884	1.3	Rocky area	____
			Shoulder	Desert pavement	Mo112	3192	2.2	Lithic Torriorthents (100%)	Consociation
	Low Hills (Mo2)	White shallow marine limestone	Backslope	Undulating	Mo211u	19733	13.8	Typic Torriorthents(100%)	Consociation
				Gently undulating	Mo211g	25471	17.9	Typic Torripsamments(65%) Typic Haplocalcids (35%)	Association
			Footslope	Nearly level	Mo212n	21677	15.2	Typic Haplocalcids (85%) Typic Torripsamments(15%)	Consociation
				Almost flat	Mo212a	21956	15.4	Typic Haplocalcids (100%)	Consociation
				Flat	Mo212f	3917	2.7	Typic Torriorthents(100%)	Consociation
				Lakes	Mo212k	1496	1.0	____	____
				Sabkha	Mo212b	902	0.6	Vertic Aquisalids (100 %)	Consociation
				Marshes	Mo212m	1854	1.3	Lithic Aquisalids(100%)	Consociation
				Urban	Mo212ur	323	0.3	____	____
Plain (Pa)	Alluvial Plain (Pa1)	Sandstone with limestone	Tread	__	Pa111	37193	26.1	Typic Torriorthents(100%)	Consociation
				Rock outcrops	Pa111r	255	0.2	____	____
				Sand sheet	Pa111s	2834	2.0	Typic Torriorthents(100%)	Consociation

Fed. = 4200 m^2

The rating values (Sys et al., 1991) were calculated to express the capability of land characteristics. The rating values and the kind of limitations are presented in Table (3). Accordingly, the studied area could be classified into four current classes and four sub classes reflect the kind of limitations in the studied area Fig. (4a).

Current class S_2 with capability index Ci varies between 50.0 and 63.0 %.

This class includes the soils which are moderately suitable. Only one subclass S_2x was found in this class. This subclass includes the moderately suitable soils which occupies an area of ~ 63066 fed. (44.2% of the total area). The soils of this subclass are affected by moderate limitations. Texture is the limiting factor for these soils whereas texture is ranging from sand to sandy clay loam (Table 2). It includes three mapping units:

Mo212a (21956 fed.), Mo212f (3917 fed.) and Pa111 (37193 fed.).

Current class S_3:

This class includes the soils which are marginally suitable. The soils have moderate limitations. It forms about 48.9 % of the studied area (69715 fed.). Three subclasses were recognized in this class as follows:

Subclass S_3 xn: It covers 21677 fed. (15.2 % of the studied area). It includes the soils of nearly level (Mo212n). Texture and salinity are the limiting factors for these soils as soil texture is sandy to sandy clay loam and EC values vary between4.0 to 9.5 dS/m (Table 2).

Subclass S_3 tx: It occupies only 2.0 % of the studied area. It is represented by soils of unit Pa111s which covered by sand sheet (75 % of surface area). Texture and topography are the limiting factors in theses soils. The soils are sandy to loamy sand and topography is gently undulating.

Subclass S_3txn: It covers ~ 31.7 % of total studied area. It includes two mapping units: Mo212u (19733 fed.) and Mo212g (25471 fed.). The soils are affected by moderate limitations. Slope, texture and salinity are the limiting factors for this subclass. The soils have gently undulating to undulating surface with slope ranges from 4 to 6 %. The soil texture ranges from sand to sandy clay loam. These soils are moderately to highly saline (EC values range from 4.5 to 22.5 dS/m).

Table (2): Range of some chemical, physical and fertility characteristics of physiographic units.

Mapping unit	Texture	pH	ECe dS/m	$CaCO_3$ %	Gypsum %	OM %	CEC (Cmol / kg)	ESP %	Depth cm	Available water %
Mo111	-	-	-	-	-	-	-	-	-	-
Mo112	SL	7.7 - 7.9	14.7 – 17.2	3.7–9.3	0.1 - 0.2	0.2	4.0	21.6 - 27.5	25	6.0 – 8.6
Mo211u	LS – SL	7.2 – 7.7	4.5 – 9.5	2.8 – 8.6	0.1 - 0.2	0.1 - 0.2	3.0 – 16.2	10.2 – 14.8	>150	3.6 – 16.9
Mo211g	S – SCL	7.5 – 8.0	7.0 – 22.5	3.1 – 17.3	0.1	0.1 - 0.2	2.5 – 10.4	11.1 – 14.6	>150	3.3 – 11.0
Mo212n	S – SCL	7.4 – 8.0	4.0 – 9.5	2.5 – 31.5	0.1 - 0.2	0.1 - 0.2	3.0 – 16.0	10.0 – 14.7	>150	3.0 – 12.5
Mo212a	LS – SL	7.7 – 8.0	1.5 – 6.9	9.5 – 23.6	0.1 - 0.2	0.1 - 0.2	3.0 – 10.5	6.5 – 14.5	>150	3.5 – 11.0
Mo212f	SL	7.4 – 7.9	3.6 – 8.9	4.3 – 7.6	0.1	0.1 - 0.2	2.6 – 16.1	11.1 – 14.9	>150	4.0 – 15.2
Mo212k	-	-	-	-	-	-	-	-	-	-
Mo212b	C	7.5 – 7.9	40.3 – 66.5	4.3 - 22.5	0.1 - 0.2	1.0 – 3.2	35.7 – 38.2	13.6 – 18.5	45-70	20.0 – 29.8
Mo212m	LS	7.5 – 7.9	34.8 – 71.9	2.0 – 13.5	0.1	0.1	3.7 – 4.3	10.0 – 18.9	40-65	4.0 – 5.1
Mo212ur	-	-	-	-	-	-	-	-	-	-
Pa111	LS – SL	7.7 – 8.0	3.3 – 9.8	4.5 – 9.8	0.1 - 0.6	0.1 - 0.3	2.6 – 18.0	8.6 - 14.7	>150	3.0 – 17.0
Pa111r	-	-	-	-	-	-	-	-	-	-
Pa111s	S - LS	7.8 – 8.0	1.0 - 6.7	2.5 – 5.3	0.1 - 0.2	0.1 - 0.2	3.0 – 9.8	9.3 – 14.0	>150	3.8 – 10.7

Table (3) Rating of limitations and current land capability classes and subclasses of the studied area.

Mapping unit	Profile No.	Slope	Drainage	Soil Characteristics (s)				Capability Index (CI) %	*Class*	Subclass
				Texture (x)	Depth (d)	$CaCO_3$ (k)	Salinity and Alkalinity(n)			
Mo111	-	-	-	-	-	-	-	-	N_2	N_2
Mo112	27	75	50	70	25	90	75	4.4		
	28	75	50	70	25	90	80	4.7		
Mo211u	8	75	100	60	100	100	85	38.3	S_3	S_3txn
	9	75	100	70	100	100	90	47.3		
	21	75	100	60	100	100	96	43.2		
	29	75	100	60	100	100	90	40.5		
Mo211g	6	80	100	50	100	90	85	30.6		
	7	80	100	70	100	100	85	47.6		
	20	80	100	50	100	100	96	38.4		
Mo212n	2	90	100	60	100	100	90	48.6	S_3	S_3xn
	5	90	100	70	100	90	85	48.2		
	24	90	100	50	100	90	96	38.9		
	26	90	100	50	100	90	90	36.5		
	31	90	100	60	100	90	90	43.7		
Mo212a	19	95	100	70	100	90	96	57.5	S_2	S_2x
	25	95	100	65	100	90	90	50.0		
	30	95	100	70	100	90	90	53.9		
	34	95	100	70	100	90	96	57.5		
Mo212f	22	100	100	70	100	90	90	56.7		
	23	100	100	70	100	100	90	63.0		
Mo212b	4	100	40	75	60	100	50	9.0	N_1	N_1
	12	100	40	75	60	100	30	5.4		
	17	100	40	75	60	90	30	4.9		
Mo212m	3	100	50	60	60	100	50	9.0		
	13	100	50	60	60	100	50	9.0		
Pa111	1	95	100	70	100	100	90	59.9	S_2	S_2x
	10	95	100	70	100	100	90	59.9		
	11	95	100	60	100	100	90	51.3		
	15	95	100	70	100	100	90	59.9		
	32	95	100	70	100	100	90	59.9		
Pa111s	14	80	100	60	100	100	90	43.2	S_3	S_3tx
	16	80	100	60	100	100	90	43.2		
	18	80	100	60	100	100	96	46.1		

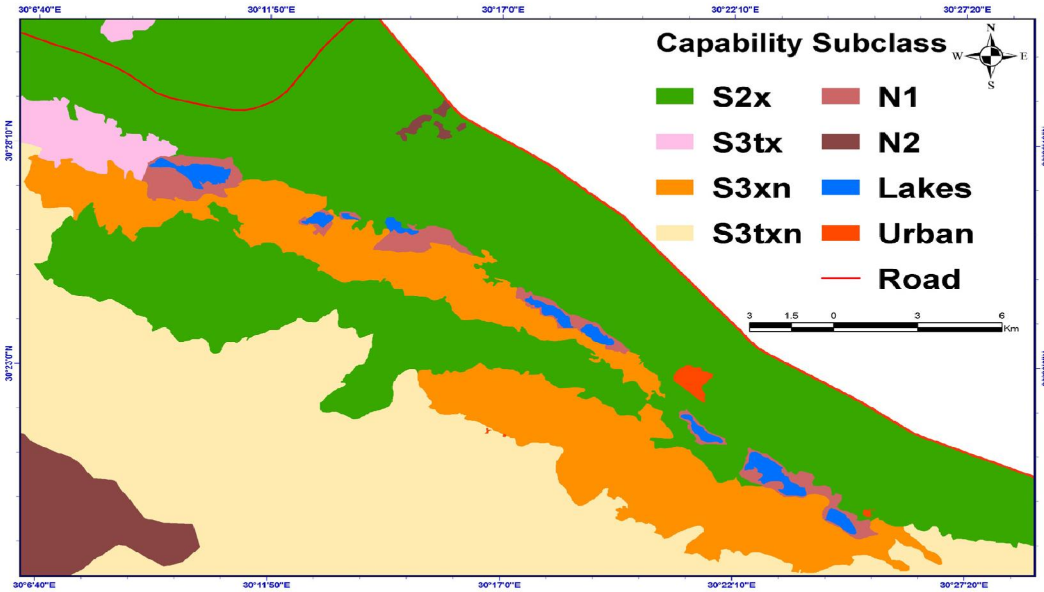

Fig. (4a) Current land capability map of the studied area.

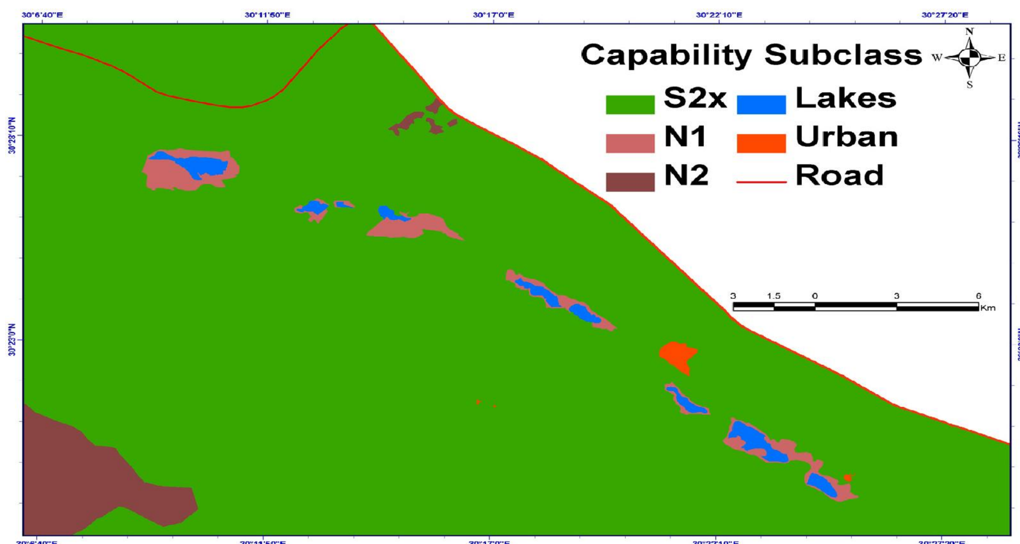

Fig. (4b) Potential land capability map of the studied area.

Class N_1:

The soils have very severe limitations. Depth, salinity, drainage and texture are the limiting factors for these soils. This class covers only ~ 1.9 % of the studied area. The capability index Ci is < 25 %. It includes two mapping units which are Mo212b and Mo212m.

Class N_2:

The soils of this class have very severe limitations which can not be corrected. The capability index Ci is < 25 %. This class covers an area of about 5331 fed. (~ 3.8 % of the studied area). The soil is not suitable for agriculture as it is rocky land. It includes three mapping units which are Mo111, Mo112 and Pa111r.

Potential land capability

Potential capability refers to the capability of units for a defined use, after specified major improvements have been completed where necessary (FAO, 1976).

In the study area the major improvements needed to overcome the current (present) limitations are:

1) Leaching of salinity (up to EC < 6 dS/m).

The leaching requirements for reclamation (LRR) to maintain soil salinity at a minimum level (< 6 dS/m) are calculating using the equation proposed by

Hoffman (1980). The (LRR) values for coarse texture soils are 1575 m^3/fed for soils with EC 22.5 dS/m

$$\frac{Di}{Ds} * \frac{ECs}{ECo} = 0.1$$

Where: Di = Depth of required water irrigation,
Ds=Depth of soil,
ECs= salinity of soils after leaching and
ECo=salinity of soils before leaching

2) Construction of good drainage systems.
3) Leveling of undulating surface (up to slope < 4%).

In addition to recommended irrigation systems in coarse texture areas (drip and sprinkler), that save water and prevent rise of ground water table.

By applying these improvements the potential capability classes of the studied area are developed as S_2, N_1 and N_2 (Fig.4b).

Potential subclass S_2x: It covers an area of about 132781 fed. (about 93.1 % of the studied area). It includes the four subclasses in current land capability: S_2x (44.2%), S_3 xn (15.2 %), S_3 tx (2.0 %) and S_3txn (31.7%).

These current subclasses could be improved by leaching salinity in S_3 xn and S_3txn and by leveling the slightly undulating in S_3txn and S_3 tx. Texture is still the limiting factor for these soils.

Land suitability for specific crops:

Five crops already cultivated in the studied area were selected to asses their convenience for cultivation in the studied area. The selected crops can be grouped into three categories as follows:

1. Field crops: wheat and barley.
2. Fruit crops: grapes.
3. Fodder crops: alfalfa and fodder beet.

Soil characteristics of the different mapping units were compared and matched with the crop requirements of each land use type (crops). The matching led to the current and potential suitability (Table 4) for each crop using the parametric approach and land index as mentioned by Sys et al. (1993).

The current and potential suitability maps of the selected crops are shown in Table (4) and Figs. (5a, b, 6a, b and 7a, b – 7b).

Current suitability:

1- Soils of Backslope:

It covers about 31.7% of the studied area and includes two physiographic mapping units Mo212u (19733 fed.) and Mo212g (25471 fed.). These soils are saline, and sandy to sandy clay loam. The slope ranges from 4 to 6 %. The soils are (S_3) in its current conditions for most selected crops except for grapes the soils of Mo212u are (S_2).

2- Soils of footslope:

The soils are nearly level to flat with slope less than 2 %. It includes five mapping units. The degree of suitability differs according to the land use type (crop) requirements as follows:

a) Soils of Mo212n (nearly level)
Moderately suitable (S_2) for grapes.
Marginally suitable (S_3) for wheat, barley, alfalfa and fodder beet.

b) Soils of Mo212a (almost flat)
Moderately suitable (S_2) for grapes alfalfa and fodder beet.
Marginally suitable (S_3) for wheat and barley.

c) Soils of Mo212f (flat)
Highly suitable (S_1) for grapes.
Moderately suitable (S_2) for wheat, barley, alfalfa and fodder beet.

d) Soils of Mo212b (sabkha) and Mo212m (marshes): these soil are not suitable (N_1) for all selected crops as the soils are shallow depth and extremely saline.

3- Soils of tread:

These soils occupy an area of about 40282 fed. (28.3% of the studied area). It includes three physiographic mapping units as follows:

a) Soils of Pa111: that covers an area of about 37193 fed. (26.1%) The soils are deep, sandy loam, slightly to moderately saline and well drained. They are moderately suitable (S_2) for all selected crops.

b) Soil of Pa111s: which covers 2.0% of the studied area. These soils are deep, gently undulating and well drained. The soils are Moderately suitable (S_2) for grapes.
Marginally suitable (S_3) for wheat, barley, alfalfa and fodder beet.

c) Soil of Pa111r: which covers only 0.2 % of the studied area. The soils are rock outcrops and permanently not suitable (N_2) for all selected crops.

Potential suitability

1- Soils backslope:

The area includes two physiographic mapping units: Mo212u and Mo212g. Applying some improvements (leaching salinity and leveling of slightly undulating areas) the soils the potential suitability are:

a) Soils of Mo212u are moderately suitable (S_2) except for grapes are highly suitable (S_1).

b) Soils of Mo212g are moderately suitable (S_2) for all selected crops.

2- Soils of footslope:

It includes the physiographic units:

a) Soils of Mo212n (nearly level)
Highly suitable (S_1) for grapes.
Moderately suitable (S_2) for wheat, barley, alfalfa and fodder beet.

b) Soils of Mo212a (almost flat)
Highly suitable (S_1) for grapes.
Moderately suitable (S_2) for wheat, barley, alfalfa and fodder beet.

c) Soils of Mo212f (flat): the soils are flat, slightly saline, deep and well drained. The current suitability and potential suitability are the same as fallow:
Highly suitable (S_1) for grapes.
Moderately suitable (S_2) for wheat, barley, alfalfa and fodder beet.

d) Soils of Mo212b (sabkha) and Mo212m (marshes): these soils are not suitable (N_1) for all selected crops in current and potential suitability.

3- Soils of tread: These soils include three physiographic mapping units

a) Soils of Pa111
Highly suitable (S_1) for grapes.
Moderately suitable (S_2) for wheat, barley alfalfa and fodder beet.

b) Soil of Pa111s: The soils are highly suitable (S_1) for grapes; moderately suitable (S_2) for wheat, barley alfalfa and fodder beet.

c) Soil of Pa111r: The soils are rock outcrops and permanently not suitable (N_2) for all selected crops.

Conclusions

The results indicate that about 3.8% of the studied area (5331 fed.) is permanently not suitable for agriculture, 48.9% are marginally suitable and 44.2% are moderately suitable. Texture, salinity and slope are the limiting factors. By applying improvements the potential capability of the soils are developed. 93.1% of the soils are moderately suitable (S_2x), texture is still the limiting factor for these soils. The results also indicate that the grapes is the best crop followed by alfalfa and fodder beet in the studied area.

Table (4): Current and potential suitability of mapping units for the selected crops

Crop		Mapping unit											
		Mo212u		Mo212g		Mo212n		Mo212a		Mo212f		Pa111	
		Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps
Field crops	Wheat	S_3	S_2	S_3	S_2	S_3	S_2	S_3	S_2	S_2	S_2	S_2	S_2
	Barley	S_3	S_2	S_3	S_2	S_3	S_2	S_3	S_2	S_2	S_2	S_2	S_2
Fruit	grapes	S_2	S_1	S_3	S_2	S_2	S_1	S_2	S_1	S_1	S_1	S_2	S_1
Fodder crops	alfalfa	S_3	S_2	S_3	S_2	S_3	S_2	S_2	S_2	S_2	S_2	S_2	S_2
	Fodder beet	S_3	S_2	S_3	S_2	S_3	S_2	S_2	S_2	S_2	S_2	S_2	S_2
Crop		Mapping unit											
		Pa111s		Mo111		Mo112		Pa111r		Mo212b		Mo212m	
		Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps	Cs	Ps
Field crops	Wheat	S_3	S_2	N_2	N_2	N_2	N_2	N_2	N_2	N_1	N_1	N_1	N_1
	Barley	S_3	S_2	N_2	N_2	N_2	N_2	N_2	N_2	N_1	N_1	N_1	N_1
Fruit crops	grapes	S_2	S_1	N_2	N_2	N_2	N_2	N_2	N_2	N_1	N_1	N_1	N_1
Fodder crops	alfalfa	S_3	S_2	N_2	N_2	N_2	N_2	N_2	N_2	N_1	N_1	N_1	N_1
	Fodder beet	S_3	S_2	N_2	N_2	N_2	N_2	N_2	N_2	N_1	N_1	N_1	N_1

Cs = Current suitability Ps = Potential suitability

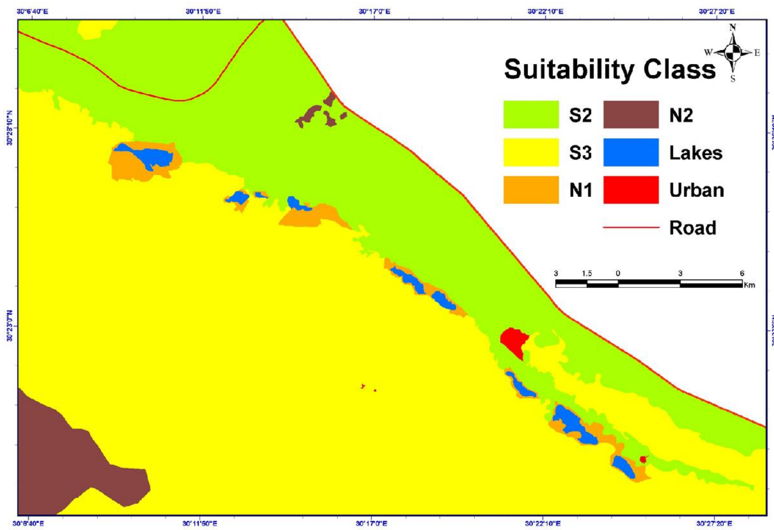

Fig. (5a) Current land suitability map of wheat and barely.

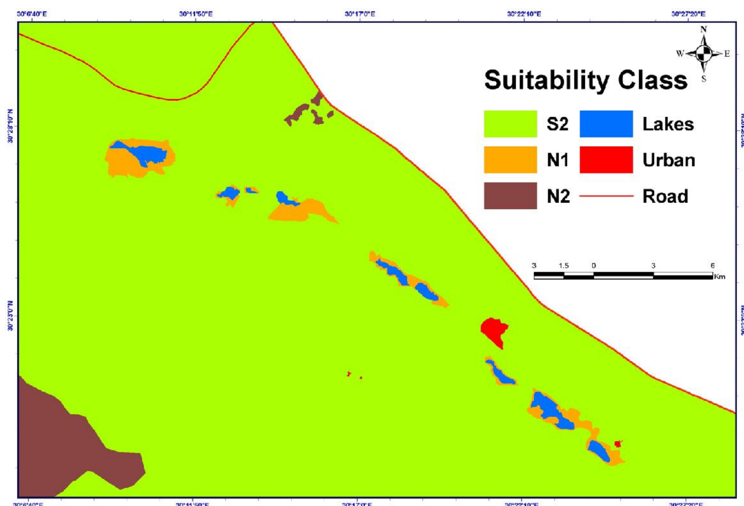

Fig. (5b) Potential land suitability map of wheat and barely.

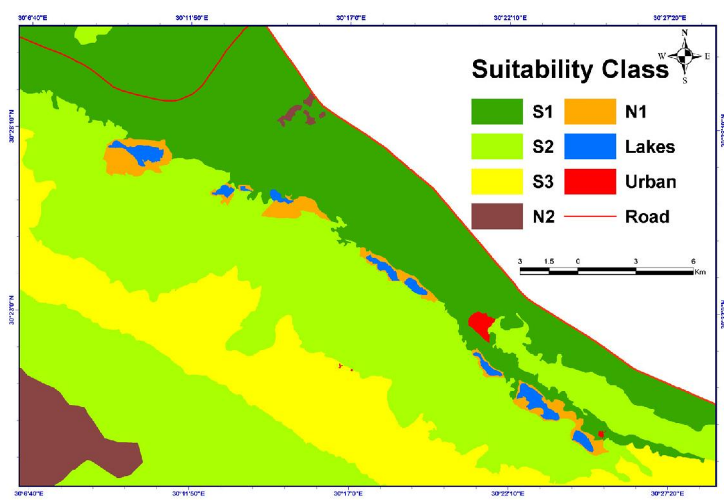

Fig. (6a) Current land suitability map of grapes.

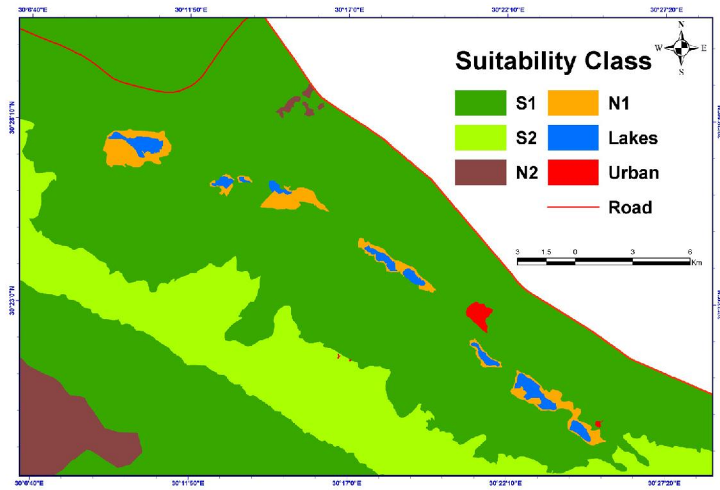

Fig. (6b) Potential land suitability map of grapes.

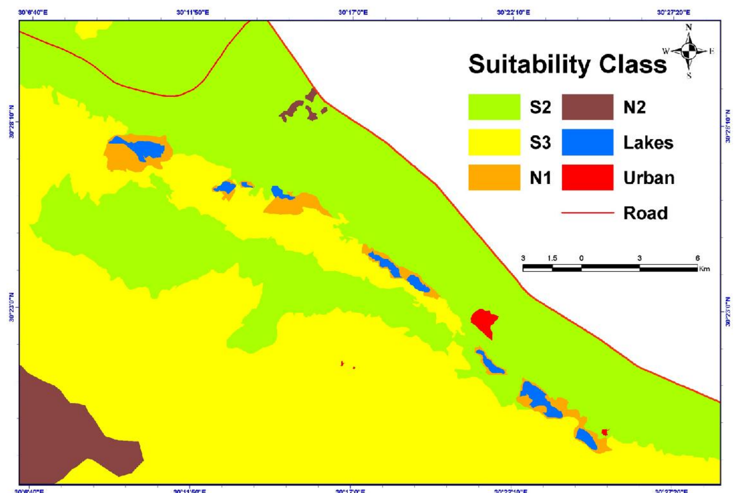

Fig. (7a) Current land suitability map of alfalfa and fodder beet.

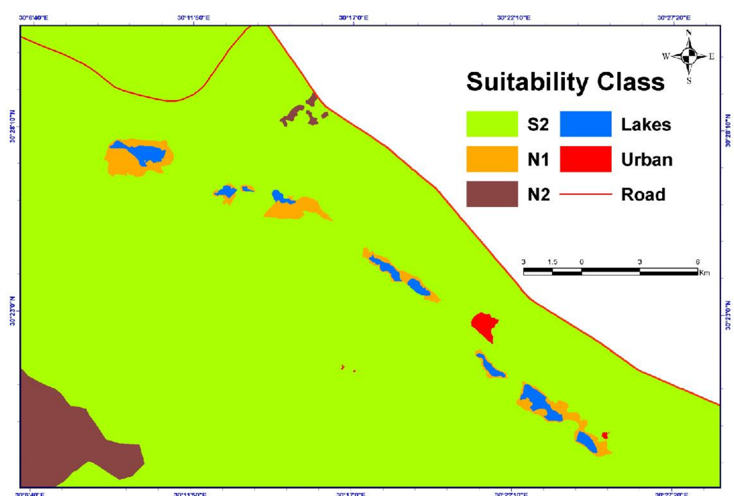

Fig. (7b) Potential land suitability map of alfalfa and fodder beet.

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