EVALUATION OF SOME SOILS IN NORTH WESTERN PARIS OASIS (EGYPT) USING STORIE INDEX AND SYS MODELS

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Abstract

The North Western of Paris Oases represents one of the highest priority areas for future development in the country. The study area is located between longitudes 30° 11′ 34.9" to 30° 26′ 59.4" East and latitudes 24° 40′ 9.3" to 24° 51′ 8.7" North and covers an area about 123966 feddans. The purpose of this study is to evaluate some soils in north western Paris oasis using Remote Sensing (RS) and Geographic Information System (GIS). For this purpose, Forty-Three soil profiles were described in the field and their representative samples were analyzed. Using geomorphological map, geological map and visual interpretation of satellite data a physiographic soil map was created to present mapping units of the study area. The area under investigation was classified into three landscape units, i.e. Plain, Dunes and Hills. Soil characteristics of the obtained mapping units were discussed and soil taxonomic unit were identified. Two models of land capability were used to evaluate the soils of study area. According to Storie Index model, the area under investigation was classified into three capability grades reflect the limitation factors, i.e. grade 1 (67.4 %), grade 3 (26.16 %) and grade 6 (6.44 %). on the other hand and according to Sys model the study area was classified into three capability classes, i.e. S_2, S_3 and N_2. The soils of S_2 have moderate limitations for agricultural crops, where texture is the main limiting factor (67.4 % of the total area). The main limiting factors of soils of S_3 are texture, depth and salinity (26.16 %), while the soils of N_2 (6.44 % of the total study area) include sand dunes, rock crops and shallow to very shallow soils. Five crops were selected to assess soil suitability for cultivation in the study area, i.e. wheat, barley, maize, tomato and olive. The results indicated that olive was more suitable for growing in such soils.

INTRODUCTION

The rapidly growing population in Egypt has a negative impact on its limited natural resources, including water and cultivated area. This requires proper management of such resources. The agricultural expansion outside the Nile Valley is one of the main objects of the Egyptian national plan (Darwish *et. al.,* 2006).

One of the ways to meet population needs is to face this negative impact by increasing production per unit area and to utilize the land with respect to its potentiality in an appropriate way. Any utilization of the land over its capability will cause soil degradation and yield reduction .

Remote sensing is defined as the acquisition of information about an object without being in physical contact with it (Elachi and Zyl, 2006). Therefore, the intrinsic characteristics of agriculture make remote sensing an ideal technique for its monitoring and management (Zhongxin *et. al.*, 2004). Geographic Information System (GIS) is considered as organized collection of computer hardware, software and spatial and non-spatial data that can help users for the efficient capture, storage, update, manipulation, analysis and management of all geographically referenced information. Remote Sensing in combination with GIS techniques proved to be effective in sustainability and planning studies (DeVries, 1985).

The fundamental principle of land evaluation is to estimate the potential of a land for different productive uses, such as farming, livestock production, or forestry, together with uses that provide services or other benefits, such as water catchment, recreation, tourism and wildlife conservation (Dent and Young, 1981). Consequently, land evaluation is a tool for strategic land use planning. A specific agricultural use and management system on land that is most suitable according to agro-ecological potentialities and limitations is the best way to achieve sustainability (FAO, 1976 b).

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 two models were used, the first is Storie Index (Storie, 1978) which revised by O'Geen and Southard (2005), and the second is sys rating systems a methodology produced by Sys *et. al.* (1991).

The Storie Index express numerically the relative degree of suitability of a soil for agricultural uses. The Storie Index assesses the productivity of a soil based on soil characteristics obtained by evaluating soil surface, depth of the soil, texture of the surface layer, slope, and manageable factors (drainage and salts). Also, the Sys rating systems were suggested under the structure of the FAO Framework for Land Evaluation (FAO, 1976 b). Moussa (1991) indicated that the Storie index and Sys system could be considered as favorable systems under the conditions prevailing in the soil of Egypt.

This present study aims to evaluate land resources of the study area as well as producing land capability map for irrigated agriculture and land suitability map for specific crops.

MATERIALS AND METHODS

1. **General description of the study area**

a) Location:

The study area is located in the south western desert in north west Paris oasis (Figure 1) between longitudes 30° 11′ 34.9" to 30° 26′ 59.4" East and latitudes 24° 40′ 9.3" to 24° 51′ 8.7" North and covers an area of about 123966 feddans.

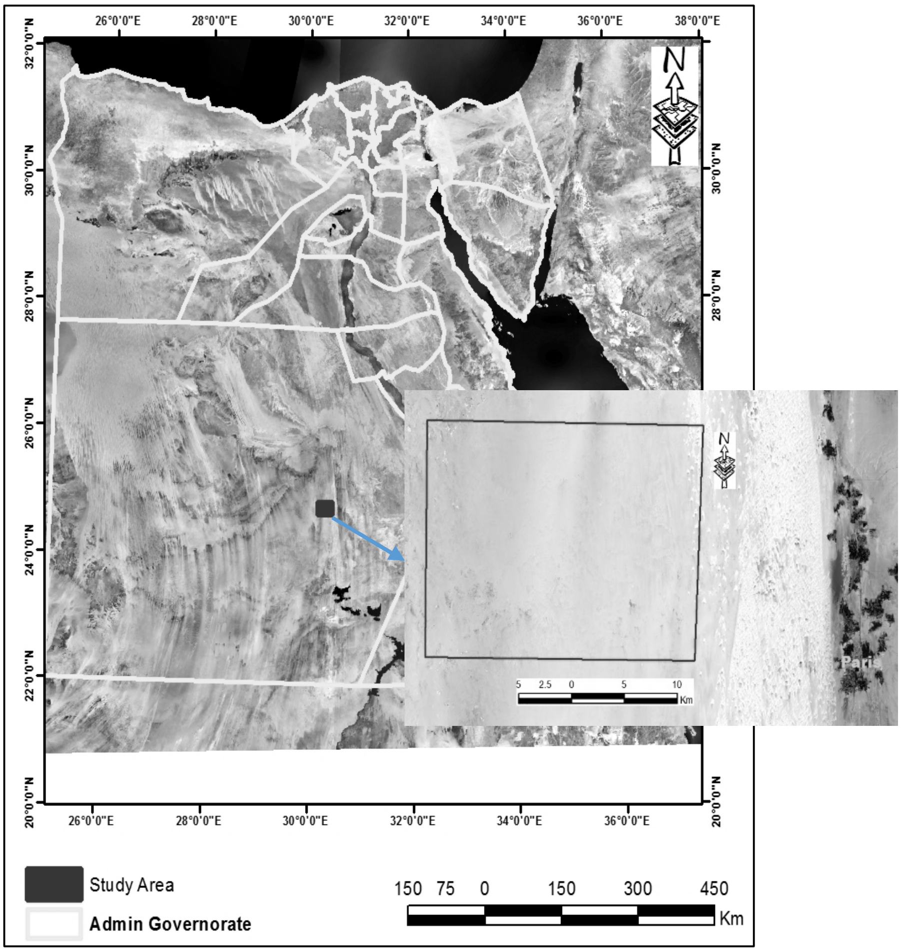

Figure 1. Location map of the study area.

b) Climate:

The area is characterized by a hot and dry summer with rare winter rainfall and bright sunshine through the year. The average annual temperature is 26.4 ˚C, while the average of evaporation is 7.76 mm (Table 1).

Table 1. The climitological norms of the study area (El Kharaga oasis meteorological station).

Month	Temperature ˚C		Relative Humidity (%)	Wind Speed (m/hr)	Sun shine (hr)	Rain (mm)	Evaporation (mm)
	highest	lowest					
January	24.6	9.2	37	2.5	8.0	0.1	6.0
February	27.7	10.6	27	2.7	8.5	٠	5.4
March	32.9	15	19	3.0	10.0	٠	6.0
April	35.9	18	17	3.1	10.4	٠	5.4
May	39.4	21.9	15	3.0	10.9	٠	8.0
June	42.4	24.5	14	2.4	12.6	٠	10.4
July	42.3	24.6	16	2.3	12.1	٠	8.7
August	44.1	25.3	17	2.7	10.1	٠	9.1
September	40.3	23.7	20	2.5	8.7	٠	9.9
October	34.6	19.4	23	2.6	8.4	٠	9.9
November	29.5	14.3	36	2.5	8.1	٠	7.7
December	24.3	9.7	38	2.7	8.0	0.1	6.6
Average	34.8	18.0	23.3	2.7	9.7	0.02	7.76

* Meteorological Authority, 2014 .

c) Geology:

According to the geological map (scale 1: 500000), produced by EGSA (1988) the sand sheets serir is the dominant formation which represents an area of about 89158 feddans (71.92%) of the total study area, covering the east part, followed by Sabaya Formation (Desert Rose Beds) representing an area of 32515 feddans (26.23 %) of the total study area, which concentrated in the western part while sand dunes while sabkha deposits cover small part in east of study area (2293 feddans represent 1.85% of the study area) (Figure 2 and Table 2).

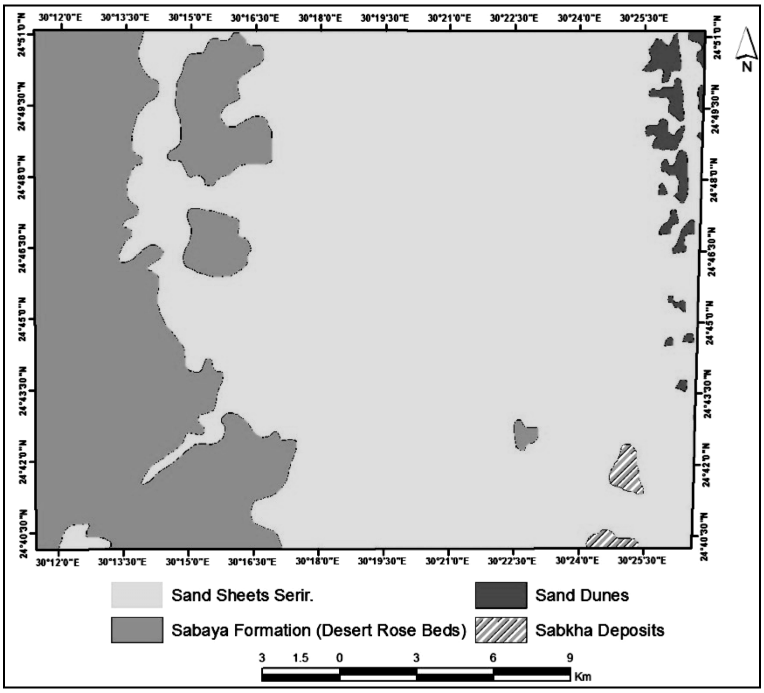

Figure 2. Geological map of the study area

Table 2. Geological formations of the study area (1: 500000)

Geological Formation	Area (feddan)	%
Sand Sheets Serir.	89158	71.92
Sabaya Formation (Desert Rose Beds)	32515	26.23
Sand Dunes	1668	1.35
Sabkha Deposits	625	0.50
Total	123966	100.0

d) Geomorphology:

According to the geomorphological map (scale 1: 250000) produced by UNDP-UNESCO (2005) the main form is Sand Sheets, which represents an area of about 84118 feddans (67.86%) of the total study area followed by Pediplains covering an area of about 35798 feddans (28.88%), while the Barchan Dunes Belts cover the rest 4050 feddans (3.26%) (Figure 3 and Table 3).

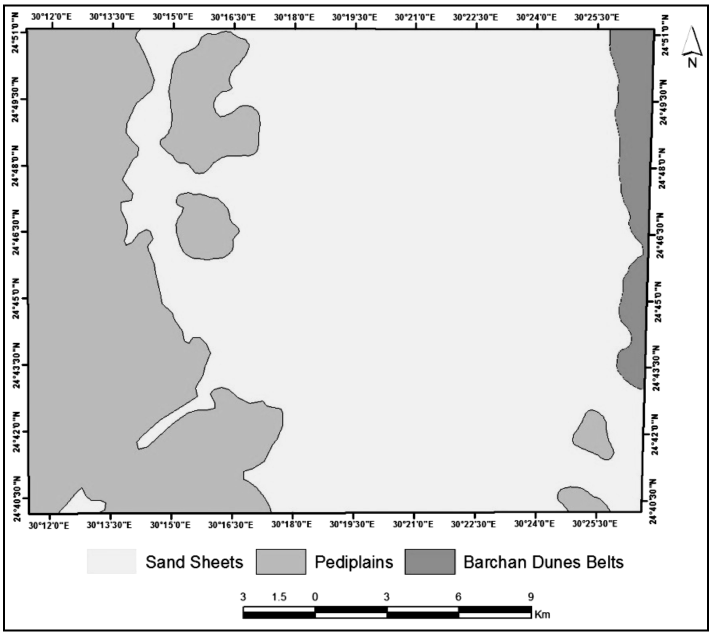

Figure 3. Geomorphological map of the study area

Table 3. Geomorphological forms of the study area (1: 250000)

Geomorphological Form	Area (feddan)	%
Sand Sheets	84118	67.86
Pediplains	35798	28.88
Barchan Dunes Belts	4050	3.26
Total	123966	100.0

e) **Satellite data:**

The data of landsat eight {Landsat-8 image scene 176-43 (20/4/2014) with spatial resolution of 30 m. and spectral resolution of the bands 5, 4 and 3} were used for delineating the physiographic units of the study area by the visual analysis, using the physiographic approach as proposed by Zinck (1988). This approach is based on the spectral signature of land features on the image. Image processing techniques were followed to produce the best possible enhanced image for visual interpretation. Spatial enhancement was done to have an output image with enhanced edges that related to soil. The pixel values are not manipulated individually but in relation to their four neighbors. This modifies the value of each pixel on neighboring brightness values (Daels, 1986). Colour enhancement was done to create new images from original in order to increase the amount of information that can be visually interpreted from the data.

The data and the output maps used the parameters for GIS displays were Egyptian Transverse Mercator projection (ETM) (Daels, 1986).

2. Field Work:

Forty-three soil profiles were taken to represent the different mapping units of the study area. Twenty minipits were used for checking the boundaries between mapping units. Field work was done in Soil Survey Department and Remote Sensing Unit. Morphological descriptions were worked out for the soil profiles in the field according to FAO (2006) and classified according to the Soil Taxonomy System (USDA, 2010). The ground truth for the different physiographic units was conducted.

Soil representative samples of the different layers of soil profiles were taken for laboratory analyses

3. Laboratory Analyses:

The collected soil samples were air dried, crushed and prepared for laboratory analyses. Laboratory analyses were carried out for particle size distribution using the pipette method (Piper, 1950), calcium carbonate content using Collin's calcimeter (Black, 1982), gypsum content by precipitation with acetone and soil pH in the soil suspension 1:2.5 using pH meter and salinity as electrical conductivity (EC) in the soil paste extract (Jackson,1976).

4. Building up Digital Georeference Database:

The spatial data include vector data (shape files) use points and polygons to represent map features, while non spatial data include attributes information. The different soil attributes were coded and new fields were added and linked to the profile database file in Arc GIS 10.2 software. Each soil profile was geo-referenced using the Global Position Systems (GPS).

The following is an example of database of soil profiles and main chemical and physical properties as shown by Arc GIS 10.2 software.

Table

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OBJECTID *	Profile_No	Depth	Rating	EC_dS_m	Rating_1	Texture_Class	Rating_2	CaCO3	Rating_3	Gypsum	Rating_4
1	10	0-50	1	0.4	0.96	SL	0.7	2.2	1	0.06	0.96
2	10	50-70	1	0.2	0.96	S	0.6	4.5	1	0.06	0.96
3	10	70-120	1	0.7	0.96	SL	0.7	3.2	1	0.3	0.96
4	9	0-50	1	1.9	0.96	S	0.6	1.5	1	1.88	1
5	9	50-100	1	6.3	0.9	LS	0.6	2.5	1	4.8	1
6	9	100-120	1	7.2	0.9	LS	0.6	2.8	1	6.26	1
7	8	0-40	1	0.1	0.96	SL	0.7	4.2	1	8.67	1
8	8	40-70	1	1.2	0.96	SL	0.7	3.5	1	1.44	1
9	8	70-120	1	5.1	0.96	SL	0.7	2.3	1	1.1	1

5. Soil Units and Land Capability:

Soils were categorized to the level of soil units according to Zinck (1988). Land evaluation for the purpose of the agricultural capability was assessed according to two methods:

Method 1: Storie Index (Storie, 1978) revised by O'Geen and Southard (2005) as a method for land evaluation according to the equation:

Storie index **=**Factor A/100 x Factor B/100 x Factor C/100 x Factor X/100 x100

These factors are: (A) soil depth, (B) texture of the surface soil, (C) slope and (X) other factors or limitations (drainage and salts were taken as limiting factors in the study area). Each of these four general factors is evaluated on the basis of a "100 percent" rating. A rating of 100 percent expresses the most favorable, or ideal condition, and lower percentage ratings are given for conditions less favorable for crop production.

Capability grades classified according to the value of the index as follows:

Grade	Index Rating	Definition
1 – Excellent	80 through 100	Soils are well suited to intensive use for growing irrigated crops.
2 – Good	60 through 79	Soils are good agricultural soils.
3 – Fair	40 through 59	Soils are only fairly well suited to general agricultural use and are limited.
4 – Poor	20 through 39	Soils are poorly suited. They are severely limited in their agricultural potential.
5 – Very Poor	10 through 19	Soils are very poorly suited for agriculture and seldom cultivated
6 – Non agricultural	Less than 10	Soils are not suited for agriculture at all due to very severe to extreme physical limitations.

Method 2: Land Capability techniques were done using the rating tables suggested by FAO (1985), Sys and Verheye (1978) and Sys et al. (1991) as common method for land evaluation according to the equation:

$$Ci = \frac{t}{100} \times \frac{w}{100} \times \frac{s_1}{100} \times \frac{s_2}{100} \times \frac{s_3}{100} \times \frac{s_4}{100} \times \frac{n}{100} \times 100$$

Where:

Ci = Capability index (%)

t = Slope

w = Drainage conditions

S_1 = Texture

S_2 = Soil depth

S_3 = $CaCO_3$ content

S_4 = Gypsum content

n = Salinity and alkalinity

Capability classes arbitrary defined according to the value of the index as follows:

Capability class	Land index (Ci) %	Definition
S1	> 75	Soils are highly suitable for cultivating all crops.
S2	75-50	Soils are moderately suitable for agriculture
S3	50-25	Soils are marginally suitable for agriculture
N	< 25	Soils are not suitable for agriculture

7. Land suitability assessment for specific crops.

The assessment of land suitability for five different land use types (LUT) has been conducted for soil units using Sys *et. al,* (1993) by implementing the FAO Framework for Land Evaluation (FAO, 1976 b). Soil characteristics of the different mapping units were compared and matched with the requirements of each crop. The suitability maps were produced.

RESULTS AND DISCUSSION

1. Physiographic soil map

Visual interpretation was done on false colour composite of bands 5, 4, 3 scale 1:100000 to produce a base map according to the difference in landscape and relief for the field work activities (Zinck, 1988).

The integration between geology and geomorphology and visual interpretation was carried out to produce a base map. This base map was used in the field to check, confirm, correct and modify the physiographic mapping unit boundaries, coupled with the results of the field work to produce final physiographic soil map of the study area. Three landscape units were delineated, i.e. Plain (Pl), Dunes (Du) and Hills (Hi) (Figure 4 and Table 4). The mapping unit of Pl 111 belong to plain landscape unit, Du 111 belong to dunes landscape unit while Hi 111 and Hi 112 belong to hills landscape unit. All mapping units are influenced by sandstone. The plain landscape unit is located in the eastern part of the study area. The area of this unit is about 83551 feddans (67.4% of the total study area) and contains one mapping unit, i.e. Pl 111. The mapping unit of Pl 111 was represented by 30 soil profiles. Dunes landscape unit represents small part adjacent to plain unit in eastern side of study area (4050 feddans 3.27 %). Hills landscape unit is located in western part of the study area. It represents an area of about 36365 feddans. (29.33 % of the total study area) and contains two mapping units i.e. Hi 111 and Hi 112. The mapping unit Hi 112 was represented by 13 soil profiles while Hi 111 unit is out of soil profiles as rock lands.

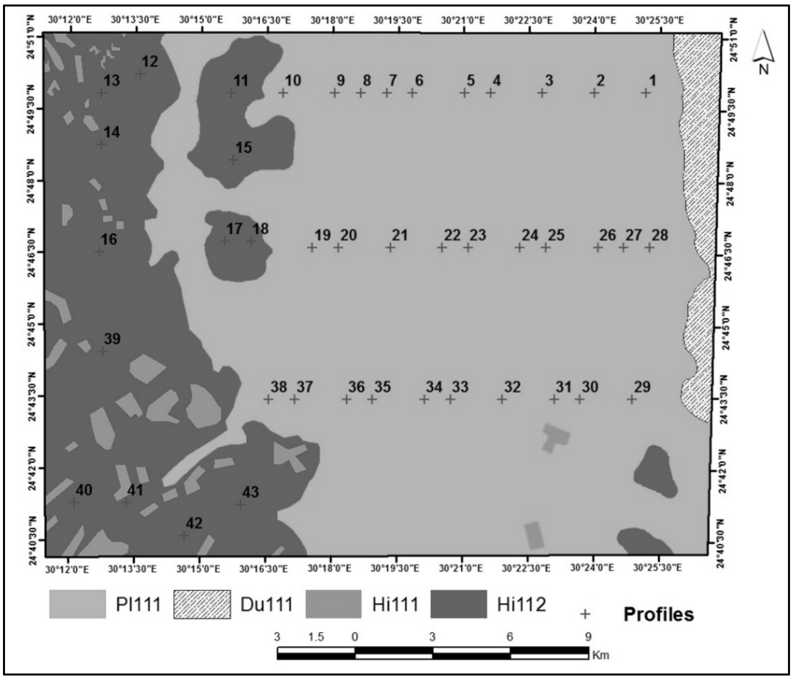

Figure 4. Location of soil profiles on Physiographic soil map of the study area

Table 4. Physiographic soil map legend

Landscape Unit	Relief	Lithology	Landform	Mapping Unit	Area	
					feddan	%
Plain (Pl)	Flat (Pl1)	Sandstone	Sand sheets	Pl 111	83551	67.40
Dunes (Du)	Rolling (Du1)	Sandstone	Barchan dunes	Du 111	4050	3.27
Hills (Hi)	Low Hills (Hi1)	Sandstone	Plateau remnants	Hi 111	3553	2.87
		Sandstone	Peidment	Hi 112	32812	26.46
Total					123966	100

The morphological description and taxonomic units of the obtained soil mapping units are summarized in Table (5).

2. Soil Properties of mapping units.

2.1. Mapping Unit Pl 111

The soils of this unit are deep (120 cm in depth), the dominant texture is loamy sand, sandy loam and sand (clay fraction is between 2.0 and 18.5 %). Most of the surface soil layers are non-saline where the EC dS/m values are less than 4 while there is no clear trend for the different layers of the soil profiles. The soils are alkaline in reaction and not sodic as pH values are more than 7 and less than 8.5 in most areas. Exchangeable sodium percentage ranges between 5.7 and 12.9. Calcium carbonate content ranges from 1 to 13.2 % except for areas effected by calcic horizon (Profiles 6, 7, 26 and 28). Most values of gypsum content are less than 5% for surface layers (Table 6) except the surface layer of profile 8 where it reaches 8.7 %.

Table 5. Morphological characteristics and taxonomic units of the studied area.

<table>
<tr><th>Mapping Unit</th><th>Surface features</th><th>Layer depth (cm)</th><th>Texture</th><th>Coarse fragment</th><th>Structure</th><th>Consistency (dry)</th><th>Secondary formation</th><th>Taxonomic unit</th></tr>
<tr><td rowspan="3">Pl 111</td><td rowspan="3">Almost flat, covered with thin sand sheet, no vegetation, 100-150m elevation above sea level</td><td>Surface up to 25</td><td>Sand or Loamy Sand</td><td><5% fine gravel</td><td>Single grains or massive</td><td>Loose to soft</td><td>Very few to common soft gypsum</td><td rowspan="3">• Sandy – Sandy skeletal, mixed families of Typic Torriorthents and Sandy mixed family of Typic Haplocalcids associations.
• Fine – loamy, mixed family of Leptic Haplogypsids as inclusions.</td></tr>
<tr><td>Subsurface up to 60-75</td><td>Sand or Loamy Sand</td><td>3 to 47% fine gravel</td><td>Massive</td><td>Soft to slightly hard</td><td>Very few to common soft lime</td></tr>
<tr><td>Subsoil up to 120</td><td>Sand or Loamy Sand or finer</td><td><5% fine gravel</td><td>Massive</td><td>Slightly hard to hard</td><td>___</td></tr>
<tr><td>Du 111</td><td colspan="7">High barchan sand dunes in rolling topographic, homogenous loose sand.</td><td>• Siliceous family of Typic Torripsamments.</td></tr>
<tr><td>Hi 111</td><td colspan="7">Plateau remnants rockland.</td><td>• Rockland</td></tr>
<tr><td rowspan="3">Hi 112</td><td rowspan="3">Gently undulating or almost flat, locally covered with stony surface, no vegetation 150 to 175m elevation.</td><td>Surface up to 25</td><td>Sand or loamy Sand</td><td>___</td><td>Massive</td><td>Soft</td><td>___</td><td rowspan="3">• Sand, mixed family of Typic - Lithic Torriorthents associations.
• Sand, mixed family of Typic Hapocalcids as inclusions.</td></tr>
<tr><td>Subsurface up to 40-70</td><td>Sand or loamy Sand</td><td>Partly with common sandstone</td><td>Massive</td><td>Soft to hard</td><td>Very few to common soft lime</td></tr>
<tr><td>40+ to 70+</td><td colspan="5">Sandstone.</td></tr>
</table>

Table 6. Chemical and physical properties of Pl 111 mapping unit

Profile No	Depth	pH (1:2.5)	EC dS/m	S* %	Sl* %	C* %	Texture Class**	$CaCO_3$	Gypsum	ESP	Gravel %
1	0-15	7.8	2.2	92.0	2.2	5.8	S	13.2	0.7	8.3	4
	15-120	7.4	13.4	82.3	8.1	9.6	LS	2.0	0.1	11.1	36
2	0-20	7.4	3.4	85.8	11.2	3.0	LS	1.6	3.5	8.4	3
	20-120	7.5	0.9	81.7	9.8	8.5	LS	2.5	1.7	5.7	42
3	0-20	7.7	9.7	93.1	4.9	2.0	S	1.4	2.5	6.3	4
	20-60	7.9	7.6	83.8	11.5	4.7	LS	5.6	1.8	7.7	37
	60-120	7.4	8.6	92.6	3.9	3.5	S	1.4	2.5	9.3	3
4	0-30	7.5	0.8	75.5	10.5	14.0	SL	4.9	2.5	7.5	17
	30-70	7.7	3.0	76.7	9.6	13.7	SL	5.6	3.3	7.9	40
	70-120	7.7	3.2	79.0	13.1	7.9	SL	4.2	2.6	8.3	17
5	0-30	7.6	4.5	75.0	11.0	14.0	SL	1.9	5.9	7.9	9
	30-50	7.8	7.1	73.0	14.0	13.0	SL	1.9	5.9	6.3	42
	50-120	7.8	13.2	61.5	21.8	16.7	SL	2.3	4.3	9.2	4
6	0-25	8.0	0.8	85.0	12.4	2.6	LS	5.4	3.4	10.2	13
	25-50	7.6	6.1	75.3	11.7	13.0	SL	17.5	4.4	11.2	6
	50-120	7.5	6.0	77.0	10.5	12.5	SL	5.9	3.7	12.1	6
7	0-20	7.4	1.8	91.6	5.7	2.7	S	9.1	3.3	8.3	17
	20-40	7.5	6.3	85.8	11.5	2.7	LS	16.9	2.4	9.2	7
	40-120	7.5	7.3	86.0	10.7	3.3	LS	11.2	3.1	10.3	10
8	0-40	7.4	0.1	72.9	17.6	9.5	SL	4.2	8.7	11.1	23
	40-70	8.4	1.2	72.9	17.6	9.5	SL	3.5	1.4	7.9	44
	70-120	8.0	5.1	75.3	11.7	13.0	SL	2.3	1.1	8.5	25
9	0-50	8.2	1.9	93.1	4.9	2.0	S	1.5	1.9	9.3	30
	50-100	7.9	6.3	83.8	11.5	4.7	LS	2.5	4.8	10.2	47
	100-120	7.9	7.2	85.8	11.2	3.0	LS	2.8	6.3	11.3	40
10	0-50	7.6	0.4	72.9	17.6	9.5	SL	2.2	0.1	12.9	30
	50-70	7.4	0.2	91.4	5.7	2.9	S	4.5	0.1	10.3	40
	70-120	7.8	0.7	76.2	10.1	13.7	SL	3.2	0.3	10.5	20
19	0-20	7.5	0.8	84.6	11.4	4.0	LS	4.5	0.1	10.1	4
	20-50	7.4	0.9	85.1	10.9	4.0	LS	1.8	0.2	9.3	47
	50-120	7.9	1.1	90.0	6.6	3.4	S	5.3	0.2	9.2	4
20	0-20	7.8	0.4	90.5	6.9	2.6	S	10.0	0.2	9.0	3
	20-80	7.3	3.8	94.7	2.5	2.8	S	2.0	0.2	8.7	46
	80-120	7.8	3.1	92.2	4.3	3.5	S	7.5	0.5	7.6	5
21	0-20	7.7	0.3	93.8	3.5	2.7	S	2.7	2.7	8.7	4
	20-120	7.4	3.3	86.1	10.6	3.3	LS	3.8	1.3	10.2	44
22	0-40	8.1	5.0	85.2	11.0	3.8	LS	11.2	3.0	10.3	3
	40-120	8.0	9.5	82.4	15.0	2.6	S	5.6	2.7	10.0	33
23	0-45	7.8	1.8	79.4	15.0	5.6	LS	6.3	4.0	10.1	4
	45-120	7.9	2.3	85.3	11.2	3.5	LS	7.1	3.2	9.5	47
24	0-20	7.7	0.3	85.1	10.9	4.0	LS	10.5	1.5	11.2	5
	20-120	7.4	3.3	89.0	6.4	4.6	LS	5.6	1.4	11.3	37
25	0-15	8.1	1.7	90.0	5.1	4.9	S	3.0	0.2	11.2	4

* S = Sand, Sl = Slit and C = Clay
** S= Sand, LS = Loamy Sand, SL=Sandy Loam, SCL = Sandy Clay Loam, CL= Clay Loam and C= Clay

Table 6. cont.

Profile No	Depth	pH (1:2.5)	EC dS/m	S* %	SI* %	C* %	Texture Class**	$CaCO_3$	Gypsum	ESP	Gravel %
	15-120	7.6	10.6	87.8	7.4	4.8	LS	2.5	1.1	10.3	37
26	0-20	7.6	8.5	90.3	6.6	3.1	S	6.2	1.1	12.3	5
	20-60	7.7	9.6	83.7	10.0	6.3	LS	16.5	5.2	11.5	35
	60-120	7.8	5.3	76.2	18.2	5.6	LS	5.1	3.2	11.2	4
27	0-60	7.5	0.7	61.5	21.8	16.7	SL	1.9	0.1	12.1	5
	60-120	7.7	1.2	61.5	21.8	16.7	SL	2.0	0.3	10.9	37
28	0-30	7.5	0.5	79.3	15.1	5.6	LS	5.5	2.1	10.7	5
	30-60	7.5	0.1	77.3	13.4	9.3	SL	16.9	1.9	10.6	7
	60-120	7.5	0.1	83.1	13.3	3.6	LS	5.6	0.1	10.5	3
29	0-20	7.9	4.3	69.2	13.3	17.5	SL	11.0	1.0	12.3	3
	20-60	7.9	14.4	30.3	36.4	33.3	CL	3.5	5.2	11.7	2
	60-120	7.5	15.2	70.3	11.2	18.5	SL	2.0	5.0	11.3	3
30	0-50	7.4	12.8	49.0	29.5	21.5	SCL	5.7	6.9	12.1	4
	50-75	7.9	15.2	35.0	31.0	34.0	CL	3.1	0.1	9.9	2
	75-120	7.6	7.7	44.0	20.0	36.0	C	5.4	1.9	9.9	2
31	0-25	7.7	6.0	64.1	17.0	18.9	SL	3.0	0.2	11.3	4
	25-120	8.3	14.5	45.0	14.5	40.5	C	5.5	2.1	11.5	5
32	0-15	7.2	0.5	85.1	11.1	3.8	LS	1.6	1.5	10.7	4
	15-120	7.4	4.1	55.7	16.5	27.8	SCL	1.7	1.2	9.9	35
33	0-20	7.7	0.6	93.1	4.9	2.0	S	2.2	2.5	8.9	4
	20-40	7.7	2.2	86.9	9.5	3.6	S	2.7	3.2	10.5	40
	40-70	7.9	3.0	85.2	10.0	4.8	LS	2.8	8.3	12.3	37
	70-120	7.7	3.8	85.8	10.2	4.0	LS	1.3	5.4	12.5	5
34	0-20	7.6	5.0	86.2	9.8	4.0	LS	4.5	2.5	12.1	6
	20-40	7.7	5.0	85.1	11.7	3.2	S	3.5	3.9	11.9	35
	40-120	8.1	14.3	87.3	8.5	4.2	LS	2.1	2.4	11.3	4
35	0-20	7.8	0.9	77.8	10.9	11.3	SL	2.0	1.5	10.3	4
	20-40	7.9	7.3	63.0	20.0	17.0	SL	2.0	1.6	10.6	40
	40-120	7.7	9.1	64.7	19.0	16.3	SL	1.8	1.3	10.6	3
36	0-20	7.9	2.7	86.2	9.8	4.0	LS	3.5	2.8	11.3	6
	20-40	8.0	4.2	83.1	13.3	3.6	LS	4.2	1.6	11.2	44
	40-120	8.0	4.6	84.5	10.9	4.6	LS	1.8	2.2	10.8	6
37	0-30	8.0	1.8	85.6	11.4	3.0	LS	7.7	0.1	10.1	5
	30-80	7.7	1.4	49.7	24.8	25.5	SCL	1.7	9.0	10.6	20
	80-120	7.4	1.3	41.1	19.7	39.2	C	1.3	8.0	10.9	4
38	0-30	7.7	0.6	85.8	10.9	3.3	LS	1.0	0.1	11.4	3
	30-120	7.9	1.1	85.8	10.2	4.0	LS	4.4	0.2	11.2	36

* S = Sand, Sl = Slit and C = Clay

** S= Sand, LS = Loamy Sand, SL=Sandy Loam, SCL = Sandy Clay Loam, CL= Clay Loam and C= Clay

2.2. Mapping Unit Hi 112

The soils of this unit are moderately deep (50-100 cm in depth) except for profiles 18, 39 and 41 where the soils are shallow to very shallow. The dominant texture is sand and loamy sand (clay fraction is between 2.0 and 4.8 %). The surface layers are saline where values of EC dS/m are more than 4 except for profiles 12, 13, and 14 (EC values are less than 2 dS/m). The soils are alkaline as pH values are more than 7 while, exchangeable sodium percentage ranges between 9.2 and 12.4. Calcium carbonate content ranges between 0.4 and 13.3 %. Gypsum content less 2.1 % (Table 7).

Table 7. Chemical and physical properties of Hi 112 mapping unit

Profile NO	Depth	pH (1:2.5)	EC dS/m	S* %	Sl* %	C* %	Texture Class**	$CaCO_3$	Gypsum	ESP	Gravel %
11	0-50	8.2	7.4	86.5	10.6	2.9	S	10.5	5.1	10.9	4
	50-60	7.9	14.3	86.5	11.0	2.5	S	3.6	0.9	11.1	3
12	0-15	7.7	0.9	75.3	11.7	13.0	SL	4.6	0.1	9.2	2
	15-50	8.1	12.5	77.0	10.5	12.5	SL	9.8	2.0	11.5	3
	50-60	7.9	20.2	84.4	11.4	4.2	LS	7.7	2.0	11.6	3
13	0-40	7.6	0.5	93.1	4.9	2.0	S	6.8	0.3	11.2	2
	40-100	7.3	10.0	87.5	9.6	2.9	S	5.2	0.1	10.3	4
14	0-20	8.1	0.4	91.2	4.3	4.5	S	4.9	2.1	12.3	1
	20-40	8.0	19.0	91.9	4.1	4.0	S	3.8	1.7	12.4	3
	40-60	8.0	29.0	92.7	4.6	2.7	S	3.6	5.0	11.5	3
15	0-20	7.5	32.0	88.8	6.4	4.8	LS	3.5	0.1	10.5	2
	20-60	7.7	31.7	75.2	11.5	13.3	SL	7.9	0.2	10.6	4
16	0-30	7.5	5.3	86.7	10.6	2.7	S	13.3	5.2	10.9	2
	30-70	7.5	6.1	89.8	4.4	5.8	S	4.8	0.2	11.2	4
	70-100	7.5	5.4	87.3	8.5	4.2	S	0.4	0.2	10.9	2
17	0-35	7.9	6.6	91.0	5.0	4.0	S	1.4	2.1	10.3	1
	35-100	8.1	4.3	84.5	11.8	3.7	LS	4.4	0.8	11.2	3
18	0-30	7.7	5.6	66.3	17.8	15.9	SL	3.5	1.4	10.3	1
	30-45	8.0	4.8	90.4	4.3	5.3	S	7.7	1.5	10.9	3
39	0-45	7.8	7.1	92.2	3.5	4.3	S	2.1	1.8	11.2	3
40	0-25	7.7	5.9	84.2	13.2	2.6	LS	3.5	2.0	11.5	1
	25-65	7.8	7.0	88.4	8.5	3.1	LS	6.3	2.3	11.4	4
	65-90	7.8	5.7	88.7	8.0	3.3	LS	7.0	3.5	10.3	3
41	0-25	7.6	7.2	89.9	7.6	2.5	S	1.4	1.7	10.5	4
42	0-25	7.9	7.3	86.1	11.0	2.9	LS	2.6	2.0	11.6	2
	25-40	7.6	6.1	67.7	16.7	15.6	SL	4.3	0.1	11.2	4
	40-60	8.1	6.1	63.9	19.5	16.6	SL	5.2	0.1	10.9	3
43	0-25	7.9	4.1	85.3	12.7	2.0	LS	1.5	1.5	10.6	2
	25-60	7.7	6.3	85.5	10.5	4.0	LS	2.3	2.1	11.3	4

* S = Sand, Sl= Slit and C =Clay

** S = Sand, LS = Loamy Sand and SL=Sandy Loam

3. Land capability assessment

A land capability model was built using Arc GIS 10.2 software (database) and the resulting tables were imported into Arc GIS to produce the capability map. The soils of the studied area were classified according two methods:

Method 1: Based on the Storie Index model as shown in Figure (5) could be classified into three capability grades reflecting the limitation factor, i.e. grade 1, grade 3 and grade 6. The soils of grade 1 have almost no limitation factors for agricultural crops. It represent an area of about 83551 feddans (67.4 % of the total area). The soils of grade3, whereas soil depth and salinity are the main limiting factors, occupies an area of 32432 feddans (26.16 %). While the grade 6 occupies 7983 feddans (6.44 % of the total study) area including the areas of sand dunes, rockland and shallow to very shallow soils.

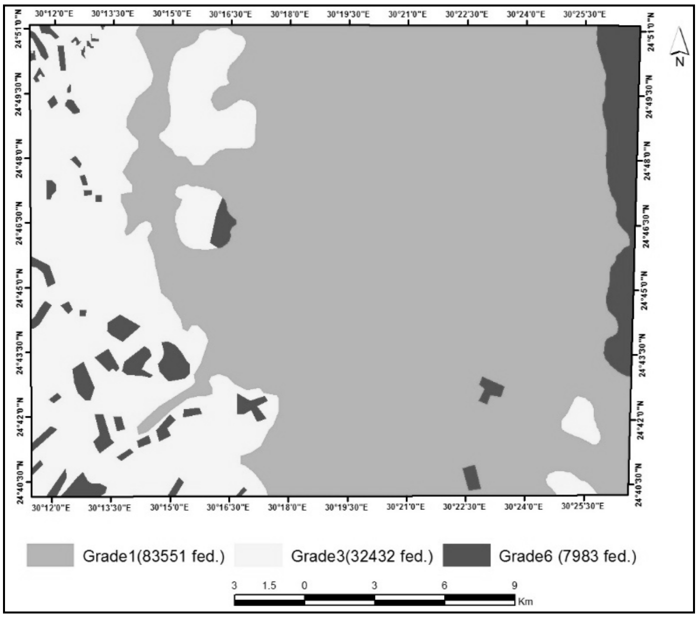

Figure 5. Land capability map of the study area according Storie Index

Method 2: Based on the Sys model as shown in Figure (6) was classified into three capability classes which reflect the limitation factors, i.e. S_2, S_3 and N_2. The soils of S_2 have moderate limitations for agricultural crops, as texture is the main limiting factor with area 83551 feddans (67.4 % of the total area). The soils of S_3 where texture, depth and salinity are the main limiting factors, occupies an area of 32432 feddans (26.16 %), while the N_2 occupied 7983 feddans (6.44 % of the total study area) including the areas of sand dunes, rockland and very shallow soils.

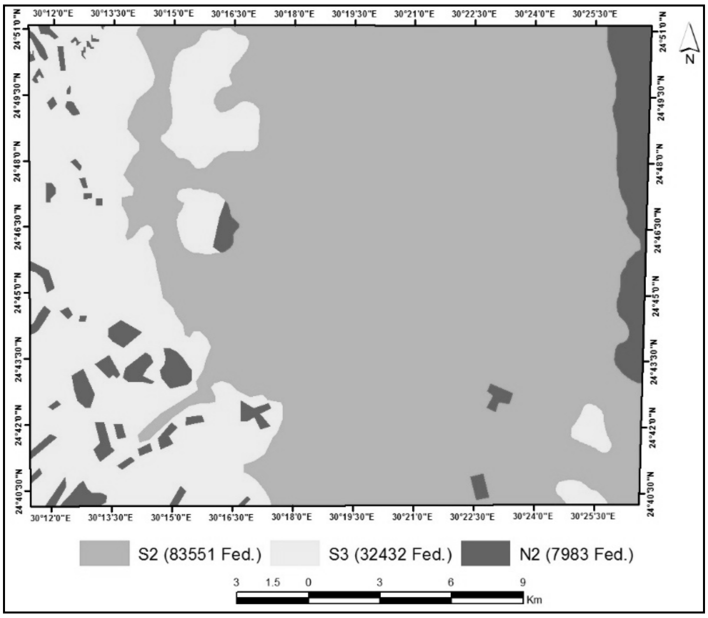

Figure 6. Land capability map of the study area according Sys model

The results of land capability indicate that capability degrees of Storie Index were grade 1 with an area of 83551 feddans (67.4 %), grade 3 occupies an area of about 32432 feddans (26.16 %) and grade 6 occupies 7983 feddans (6.44 %) that is equal to the capability classes of Sys method S_2, S_3, and N_2 with same areas, respectively. The capability index and rating of main characteristics for mapping units (Storie, 1978) are as follows :

Unit	Profile No	Depth	Texture	Slope	EC	Drainage	*Ci %	Grade
Pl 111	1	1	0.92	1	0.91	1	83.7	Grade 1
	2	1	0.92	1	0.95	1	87.4	Grade 1
	3	1	0.92	1	0.9	1	82.8	Grade 1
	4	1	0.92	1	0.95	1	87.4	Grade 1
	5	1	0.92	1	0.91	1	83.7	Grade 1
	6	1	0.92	1	0.91	1	83.7	Grade 1
	7	1	0.92	1	0.91	1	83.7	Grade 1
	8	1	0.92	1	0.95	1	87.4	Grade 1
	9	1	0.92	1	0.95	1	87.4	Grade 1
	10	1	0.92	1	0.95	1	87.4	Grade 1
	19	1	0.92	1	0.95	1	87.4	Grade 1
	20	1	0.92	1	0.95	1	87.4	Grade 1
	21	1	0.92	1	0.95	1	87.4	Grade 1
	22	1	0.92	1	0.95	1	87.4	Grade 1

*Ci = Capability index

Cont.

Unit	Profile No	Depth	Texture	Slope	EC	Drainage	*Ci %	Grade
	23	1	0.92	1	0.95	1	87.4	grade 1
	24	1	0.92	1	0.95	1	87.4	grade 1
	25	1	0.92	1	0.91	1	83.7	grade 1
	26	1	0.92	1	0.91	1	83.7	grade 1
	27	1	0.92	1	0.95	1	87.4	grade 1
	28	1	0.92	1	0.95	1	87.4	grade 1
	29	1	0.92	1	0.85	1	78.2	grade 1
	30	1	0.92	1	0.85	1	78.2	grade 1
	31	1	0.92	1	0.91	1	83.7	grade 1
	32	1	0.92	1	0.91	1	83.7	grade 1
	33	1	0.92	1	0.91	1	83.7	grade 1
	34	1	0.92	1	0.91	1	83.7	grade 1
	35	1	0.92	1	0.95	1	87.4	grade 1
	36	1	0.92	1	0.9	1	82.8	grade 1
	37	1	0.92	1	0.95	1	87.4	grade 1
	38	1	0.92	1	0.95	1	87.4	grade 1
Hi 112	11	0.7	0.92	1	0.82	0.96	50.7	grade 3
	12	0.7	0.92	1	0.82	0.96	50.7	grade 3
	13	0.7	0.92	1	0.82	0.96	50.7	grade 3
	14	0.7	0.92	1	0.7	0.96	43.3	grade 3
	15	0.7	0.92	1	0.7	0.96	43.3	grade 3
	16	0.7	0.92	1	0.82	0.96	50.7	grade 3
	17	0.7	0.92	1	0.82	0.96	50.7	grade 3
	18	_	_	_	_	_	_	grade 6
	39	_	_	_	_	_	_	grade 6
	40	0.7	0.92	1	0.8	0.96	49.5	grade 3
	41	_	_	_	_	_	_	grade 6
	42	0.7	0.92	1	0.8	0.96	49.5	grade 3
	43	0.7	0.92	1	0.8	0.96	49.5	grade 3
Hi 112	_	_	_	_	_	_	_	grade 6
Du 111	_	_	_	_	_	_	_	grade 6

*Ci = Capability index

In addition, the capability index and rating of main characteristics for mapping units according to Sys (1991) are as follows:

Unit	Profile No	Depth	EC	Texture	Slope	Drainage	$CaCO_3$	Gypsum	*Ci %	Class
Pl 111	1	1	0.85	0.6	1	1	1	0.96	49.0	S3
	2	1	0.98	0.6	1	1	1	1	58.8	S2
	3	1	0.88	0.6	1	1	1	1	52.8	S2
	4	1	0.96	0.7	1	1	1	1	67.2	S2
	5	1	0.88	0.7	1	1	1	1	61.6	S2
	6	1	0.88	0.7	1	1	1	1	61.6	S2
	7	1	0.88	0.6	1	1	1	1	52.8	S2
	8	1	0.96	0.7	1	1	1	1	67.2	S2
	9	1	0.96	0.6	1	1	1	1	57.6	S2
	10	1	0.96	0.7	1	1	1	0.96	64.5	S2
	19	1	0.98	0.6	1	1	1	0.96	56.4	S2
	20	1	0.96	0.6	1	1	1	0.96	55.3	S2
	21	1	0.96	0.6	1	1	1	1	57.6	S2
	22	1	0.96	0.6	1	1	1	1	57.6	S2
	23	1	0.96	0.6	1	1	1	1	57.6	S2
	24	1	0.96	0.6	1	1	1	1	57.6	S2
	25	1	0.9	0.6	1	1	1	1	54.0	S2
	26	1	0.9	0.6	1	1	1	1	54.0	S2
	27	1	0.98	0.7	1	1	1	1	68.6	S2
	28	1	0.98	0.6	1	1	1	1	58.8	S2
	29	1	0.85	0.7	1	1	1	1	59.5	S2
	30	1	0.85	0.8	1	1	1	1	68.0	S2
	31	1	0.9	0.75	1	1	1	1	67.5	S2
	32	1	0.9	0.75	1	1	1	1	67.5	S2
	33	1	0.9	0.6	1	1	1	1	54.0	S2
	34	1	0.9	0.6	1	1	1	1	54.0	S2
	35	1	0.96	0.7	1	1	1	1	67.2	S2
	36	1	0.9	0.6	1	1	1	1	54.0	S2
	37	1	0.96	0.7	1	1	0.96	1	64.5	S2
	38	1	0.96	0.6	1	1	0.96	1	55.3	S2
Hi 112	11	0.6	0.8	0.6	0.9	0.96	1	1	25.0	S3
	12	0.6	0.8	0.6	0.9	0.96	1	1	25.0	S3
	13	0.85	0.8	0.6	0.9	0.96	1	1	35.3	S3
	14	0.6	0.75	0.6	0.9	0.96	1	1	23.3	N1
	15	0.6	0.75	0.6	0.9	0.96	1	1	23.3	N1
	16	0.85	0.8	0.6	0.9	0.96	1	1	35.3	S3
	17	0.85	0.8	0.6	0.9	0.96	1	1	35.3	S3
	18	–	–	–	–	–	–	–	–	N2
	39	–	–	–	–	–	–	–	–	N2
	40	0.75	0.8	0.6	0.9	0.96	1	1	31.1	S3
	41	_	_	_	_	_	_	_	_	N2
	42	0.6	0.8	0.6	0.9	0.96	1	1	25.0	S3
	43	0.6	0.8	0.6	0.9	0.96	1	1	25.0	S3
Hi 111		–	–	–	–	–	–	–	–	N2
Du 111		–	–	–	–	–	–	–	–	N2

*Ci = Capability index

Land suitability for specific crops:

Land suitability for five different crops, i.e. Wheat, Barley, Maize, Tomato and Olive was tested for the soils using Arc GIS 10.2 software. The results were imported to Arc GIS to display maps. Soil characteristics of the different mapping units were compared and matched with the crop requirements of each land use type, i.e. crop (FAO, 1976 b). The matching led to the current and potential suitability for each crop using the parametric approach and land index as mentioned by Sys *et. al.* (1993) (Table 7-8 and Figures 7-11).

4.1. Current suitability

The data in Table (8) and Figures (7, 9 and 11) show the current sutabitity classes for the selected studied crops. These data indicate that 67.4 % is highly suitable (S_1) for olive. On the other hand, 67.4 % is moderately marginally suitable (S_2) for wheat, barley, maize and tomato. The table shows that 26.16 % (S_3) is only suitable for wheat, Barley and maize. Tomato is not suitable only for N_1 (26.16 %). The area of permenanty not suitable for all crops (N_2) is 6.44 %.

Table 8. Current suitability classes and areas % for growing crops in the study area

Suitability class*	Wheat	Barley	Maize	Tomato	Olive
S1					67.4 %
S2	67.4 %	67.4 %	67.4 %	67.4 %	
S3	26.16 %	26.16 %	26.16 %		26.16 %
N1				26.16 %	
N2	6.44 %	6.44 %	6.44 %	6.44 %	6.44 %

* S_1 = Highly suitable, S_2 = Moderately suitable S_3= Marginally suitable
N_1= Currently not suitable N_2=Permanently not suitable

4.2. Potential suitability

From the previous discussion, the main limiting factors were texture and salinity which can be improved using good management practices such as salt leaching, use of organic matter amendments, construction of a good drainage system and follow good agriculture practices for crops. These improvements will raise the potential suitability.

The results in Table (9) and Figures (8, 10 and 11) show the area % of the potential suitability classes. The data show that 93.56 % of the area is moderately suitable (S_2) for wheat, barley and maize, while an area of about 6.44% is permanently not suitable (N_2) for all crops.

Table 9. Potential suitability classes and areas % for growing crops in the study area

Suitability class*	Wheat	Barley	Maize	Tomato	Olive
S1				67.4 %	67.4 %
S2	93.56 %	93.56 %	93.56 %	26.16 %	
S3					26.16 %
N1					
N2	6.44 %	6.44 %	6.44 %	6.44 %	6.44 %

* S_1 = Highly suitable, S_2 = Moderately suitable S_3= Marginally suitable
N_1= Currently not suitable N_2=Permanently not suitable

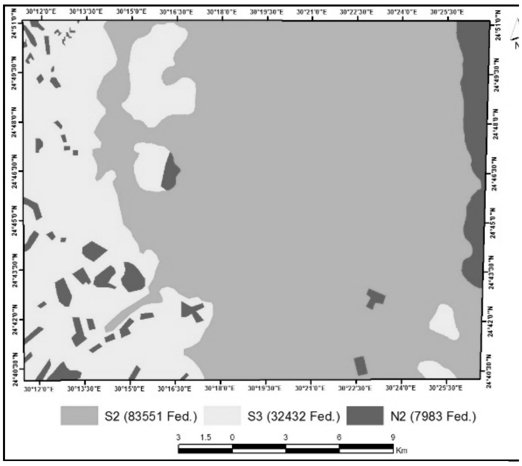

Figure 7. Current land suitability of wheat, barley and maize in the study area.

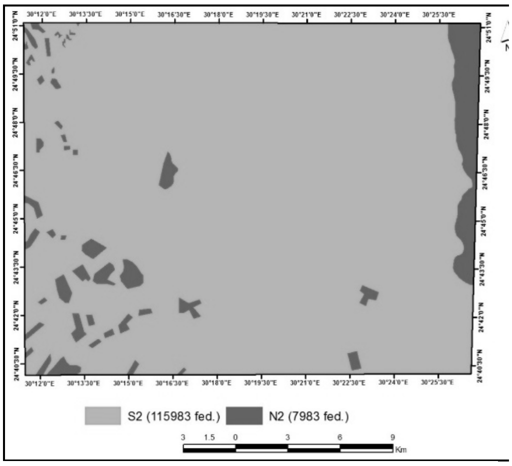

Figure 8. Potential land suitability of wheat, barley and maize in the study area.

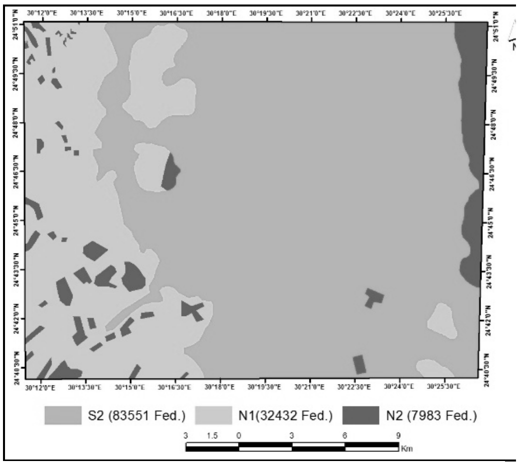

Figure 9. Current land suitability of tomato in the study area.

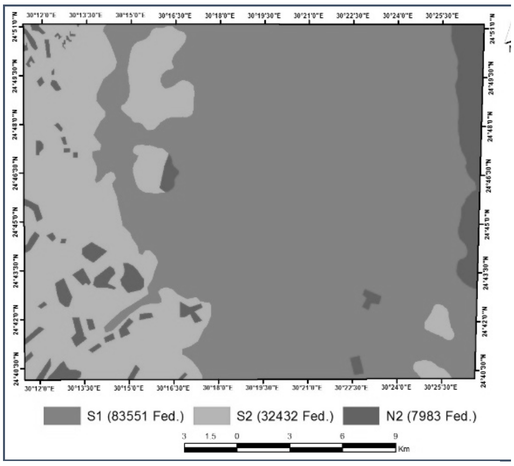

Figure 10. Potential land suitability of tomato in the study area.

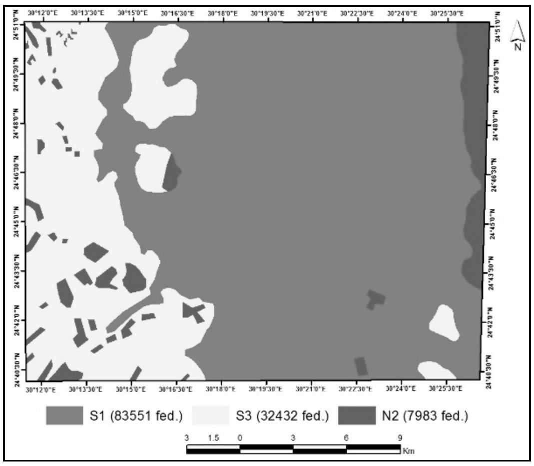

Figure 11. Current and potential land suitability of olive in the study area.

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تقييم التربة باستخدام نموذجى Sys – Storie Index في بعض مناطق شمال غرب واحات باريس–مصر

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تقع منطقة الدراسة شمال غرب واحات باريس بمحافظة الوادى الجديد بمساحة تقدر بحوالي١٢٣٩٦٦ فدان وتعتبر من المناطق الواعدة للتنمية الزراعية بهذه المنطقة. ويهدف هذا البحث الي دراسه خصائص أراضي تلك المنطقه وتقييم كفاءتها الانتاجيه وملائمتها لاستزراع المحاصيل الرئيسيه وذلك بإستخدام تقنيات الاستشعار عن البعد ونظم المعلومات الجغرافيه وتطبيق نموذجى تقييم الاراضي الجافه Storie Index- Sys

ولهذا الغرض تم إختيار وحفر ٤٣ قطاعا أرضيا ممثلا لاراضي المنطقه ، ٢٠ حفرة صغيرة ، ولقد وصفت هذه القطاعات مورفولوجيا وجمعت منها عينات تمثل الاختلافات الرأسيه لها للتحليلات المعمليه.

ولقد تم عمل خريطة فيزيوجرافية باستخدام التفسير المرئي لصورة القمر الصناعي لاندسات ٨ مع بيانات الجيولوجى والجيومورفولوجى المتوفرة عن المنطقة. ودرست الصفات المميزة لوحدات خريطة التربة المنتجة وتم التعرف على الوحدات التصنيفية السائدة بها.

وأوضح تطبيق نموذج تقييم الاراضي الجافه Storie Index متكاملا مع نتائج نظم المعلومات الجغرافيه أن أراضي المنطقه بنسبة ٦٧,٤% كانت أراضى درجة اولى والتربة لا تعانى من أية محددات أرضية، و نسبه ٢٦,١٦% درجة ثالثة تعانى من بعض مشاكل في ملوحة التربة وعمق القطاع الأرضي، بينما كانت أراضي الدرجة السادسة تشغل مساحة ٦,٤٤% وهى تمثل أراضي الكثبان الرملية والأراضي ضحلة العمق الى ضحلة العمق جدا.

وبتقييم صلاحية التربة طبقا لنموذج Sys أوضحت الدراسة أن أراضي المنطقة تقع في أقسام متوسطة الصلاحية (S_2) وحدية الصلاحية (S_3) وغير صالحة للزراعة بصفة دائمة (N_2). وتبين النتائج أن حوالي ٦٧,٤ % من اجمالي منطقة الدراسة هي أراضي متوسطة الصلاحية (S_2) وأن العامل المحدد هو قوام التربة. أما الأراضي حدية الصلاحية (S_3) فهي تغطي مساحة ٢٦,١٦% من اجمالي منطقة الدراسة وحدية الصلاحية فيها ترجع الى عمق القطاع الأرضي وقوام وملوحة التربة. بينما كانت الأراضي غير الصالحة للزراعة (N_2) تمثل مساحة ٦,٤٤%.

وقد تم اختيار خمسة محاصيل لتقييم درجة صلاحيتها للزراعة طبقا لطريقة Sys وهي والقمح والشعير والذرة الشامية والطماطم والزيتون، وتبين من النتائج أن الزيتون هو أفضل هذه المحاصيل حيث تجود زراعته بدرجة أعلى من باقي المحاصيل.