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Monitoring Land Degradation Impact on A Unique Agrobiodiversity in Siwa Oasis, Egypt

Afify, A. A.; M. M. Soliman; Mona K. M. Abdel-Razek and Hanan E. M. El Azab
Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt.

ABSTRACT

The study area is situated in north-west of Egypt. Physiographic units were delineated using satellite data of TM5 and TM8, in the years 1986 and 2018, respectively. They are mesa, pediplain (partly cultivated or waterlogged), aeolian plain (partly cultivated or waterlogged), aeolian dunes and ponded areas (artificial lakes). Other features are those of settlements and roads. Extra ponded areas from 1986 to 2018 covered 159.38, 80.56, 5296.6, 8.37, 6.70, and 34.37 hectares over pediplain, pediplain (cultivated), pediplain (waterlogged), aeolian plain and aeolian plain (cultivated) respectively. Extra waterlogged areas from 1986 to 2018 covered 4917.61, 1273.21, 3887.37, 205.32 and 23.50 hectares over pediplain, pediplain (cultivated), aeolian plain, aeolian plain (cultivated) and aeolian dunes respectively. Generally 5585.97 and 10307.0 hectares have been ponded and waterlogged respectively with total land degradation of 15892.97 hectares. Soil drainage classes versus soil taxonomic units are: (a) Excessively drained soils in aeolian plain and aeolian dunes have *Typic Torripsamments, mixed (calcareous*). (b) Well drained soils in the cultivated pediplain are dominated by *Typic Haplocalcids, fine loamy, mixed*. In cultivated aeolian plain are *Xeric Torripsamments, mixed (calcareous*). (c) Moderately well drained soils in pediplain are dominated by *Calcic Haplosalids, coarse loamy, carbonatic,* while in the cultivated area are dominated by *Aquic Haplocalcids, coarse loamy, mixed.* In cultivated aeolian plain, the soils are *Oxyaquic Torripsamments, mixed (calcareous*). d) Poorly drained soils in pediplain are dominated by *Calcic Aquisalids, fine loamy, mixed,* while in aeolian plain are *Typic Aquisalids, sandy, mixed.* (e) Very poorly drained soils are *Gypsic Aquisalids, fine* loamy, *mixed* in the pediplain but are *Gypsic Aquisalids, sandy, mixed* in the aeolian one. Land Utilization Types (LUTs) of date palm, olive and jojoba using drip irrigation were currently evaluated under soil limitations of calcareousness, drainage condition, salinity and sodicity. This current suitability can be potentially more profitable after executing land improvements for drainage, salinity and sodicity. Whenever the action of replacing surface irrigation by drip one, current cultivation expansion must be conditioned under drip irrigation in the aeolian plain. It is potentially highly suitable for olive and jojoba. Being this plain aligning the southern borders of the lakes, it has an easy access to be supported with the recycled water as subtracted from those lakes. The cultivation expansion will be more profitable for jojoba as being highly tolerant plant for salinity and marginal fertility. This water and land practice in that aeolian plain will reduce the problem of current and later on land degradation. Formal water management become a must by saving water use as well as realizing its recycling use.

Keywords: Siwa Oasis, physiography, soil drainage, soil classification and land degradation

INTRODUCTION

Siwa should be considered as a Cultural Landscape as well as to be a protectorate being reflects the interactions between indigenous people and their natural environment. This unique Oasis includes the most powerful oracles of the ancient world and still as illustrative of human society evolution and settlement over time under the influence of the physical constraints. According to UNESCO Convention (2012), Cultural landscapes on the World Heritage List are cultural properties and represent the combined works of nature and of man. This influence may opportunities presented by their natural environment and of successive social, economic and cultural forces. FAO (2016) designated Siwa Oasis as a globally significant Agricultural Heritage in situ repository of plant genetic resources, especially of uniquely adapted varieties of date palm and olive. It is distinguished by a range of archaeological treasures that testify to the long history of the oasis at the crossroads of ancient trade routes, going back to Pharaonic and Ptolemaic epochs. In the study area, this cultural landscape is currently affected by land degradation process. As the man and nature are a harmony of closed relationship, the negative effect of each other is most probably act upon both. The memory seen proved that the past of unique feature in Siwa land is partly cannot be seen within the existence of reality being become a shadow on the ground. It is highly needed to redo that past for Siwa otherwise its cultural landscape will be retreated as well as the productive cultivated land resources will be seriously deteriorated. Parallel to cultivated land retreatment, the local population in Siwa increases according to CAPMAS (2018) from 10,300 in the year 1986 to 29,809 persons in the year 2018. This problem is making worse by further land degradation resulting in a negative impact on the demographic features and also on a high level of agrobiodiversity in Siwa Oasis, which has been seriously threatened as a clearly dawned trauma.

Intensive cultivation in Siwa has long been intertwined with the over use of irrigation water in a closed system. Severe waterlogging was then initiated and consequently extensive patches have now been salinized. Abo-Ragab (2010) stated that the cultivation of olive and date palm in Siwa oasis loss annually for olive and date palm around 67.52 and 33.42 million L.E respectively with a total net revenues of about 100.94 Million LE. as a result of desertification degradation. Accordingly, large consumption of underground water is not giving enough time to this water to be renewed resulting in increasing surface water, which became an acute environmental problem. The salinization of soil has been occurred and the areas of the lakes have been increased and flooded the neighboring cultivated areas, which consequently have lands of low or none crop yield. This matter threatens the cultivation of dates and olives that are the most famous Siwan plantations. According to Afify (2009) such cultivated area is managed within the limited cultivated land resources in Egypt, which is situated in an arid zone challenging water sacristy as the water resources are limited. Formal water practice become a must by saving water use as well as realizing its recycling use. These limited cultivated areas require a national sustainable economic view rather than to be determined by uncontrolled demand of individuals. For a high level caring of this problem, the State commits to protecting land under cultivation according to the Constitution (*Destor*) of Egypt.

Accordingly, it is urgently required to activate Constitution's concept by a strict low otherwise the crises will still acting without solution (Afify *et al*., 2013).

The article aims to update the spatial and the levels of land degradation in order to find solutions for removing or reducing these level of land degradation to improve the environmental conditions and increasing productivity level. This improvement will in turn improve the social and economic status of Siwa Oasis. Also to develop an agro-ecosystems framework to assess the dynamics of land degradation to find options against this problem that suits the local farming management. Salt affected area could be utilized for raising cash-crop vegetation that can be adapted for successful life cycle.

It is a call to protect this cultural and natural heritage using an integrated management for natural, human and economic resources, which are mainly related to sustain agricultural development. This valuable system requires knowledgeable smart attitude that consider a prior strategy to protect and maintain that unique system of agriculture. Such strategy, should consider the full measure of the current problem for keeping this agrobiodiversity to still survive in Siwa Oasis by sustained management for soil and water resources as well as for the unique varieties of date palm and olives.

MATERIALS AND METHODS

1- Geography of the study area

The study area was located North-west of Egypt in Matrouh Governorate. Its coordinates in the lower left corner are latitude of $29^{O}\ 04^{-}\ 05^{=}$ N and longitude of $25^{O}\ 17^{-}\ 39^{=}$ E, while in the upper left corner are latitude of $29^{O}\ 18^{-}\ 26^{=}$ N and longitude of $25^{O}\ 17^{-}\ 37^{=}$ E. In the upper right corner, the latitude is $29^{O}\ 18^{-}\ 27^{=}$ N and the longitude is $25^{O}\ 49^{-}\ 45^{=}$ E, while in the lower right corner, the latitude is $29^{O}\ 04^{-}\ 06^{=}$ N and the longitude is $25^{O}\ 49^{-}\ 50^{=}$ E (figure 1).

2- Remote sensing data

a) Specifications of remote sensing data

Remote sensing data were recorded by Operational Land Imager (OLI) of the satellite TM8 during the year 2018 within the path 180 and row 40. The multispectral bands have spatial resolution of 30 meters. Band combination includes the spectral bands of Green (530-590 nm), Red (640-670 nm) and Near-Infrared (850-880 nm). In the case of TM5, the spectral bands are Green (0.52-0.60 nm), Red (0.63-0.69 nm), and Near-Infrared (0.76-0.90 nm)

These data were merged with panchromatic band of 15 meters spatial resolution with spectral resolution of 500-680 nm in the case of using OLI of the satellite TM8 data.

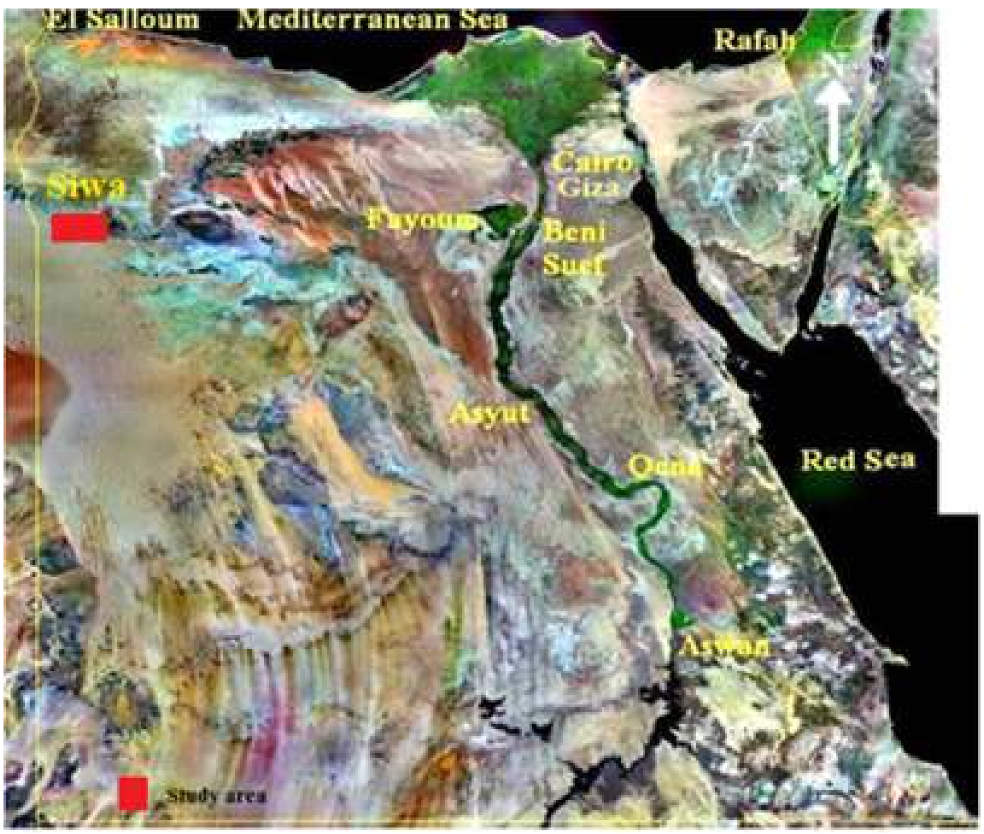

Figure 1. Location map of the study area

b) Geometric correction of remote sensing data

The raster display of remote sensing data were geometrically corrected and projected with Transverse Mercator projection in WGS-84 spheroid and datum using ground control points of geographic maps (scale 1:50000) published by the Land Survey Authority of Egypt (1990).

c) Image sub-setting

The full scene of large file was breached out into smaller files containing data that cover the area of interest (figure2) for eliminating the extraneous data in the file speeding up data processing using the cartographic software of ERDAS Inc., (2010).

d) Automated remote sensing data classification

Cultivated areas, waterlogged ones and water body were well recognized by the unsupervised classification that based on the natural groupings of pixels. According to ERDAS (2010), the clustering method is Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm to perform an unsupervised classification or clustering of the image pixels into spectral clusters. Each cluster represents a group of pixels which have similar spectral characteristics in the input bands. The band combination of green, red and near infrared radiation gave a valid clustering representing the reflectance from the cultivated areas, water body and the different drainage condition levels. The output classes were merged, recoded and converted into a polygon of a vector format.

e) Visual interpretation of remote sensing data

Physiographic units (polygons) and roads (lines) of the study area were delineated by visual analysis, using the physiographic approach of Zinck and Valenzuela (1990). These features were manipulated with the other land information as GIS layers.

3- Field work

Remote sensing interpretation and value classification maps were checked in the field by different ground observations. Soil profiles were located to represent the predominant characteristics of each physiographic unit and the intervals of classified spectral signature values. These sites were located using the Global Positioning System (GPS) as shown in figure 2. Soil profiles were dug to a depth of 150 cm, bed rock or ground water table, whichever came first. They were described using the nomenclature of the Soil Survey Manual (USDA, 2017). The elements of soil color description were determined using the Munsell soil color chart (Anon 1975).

4- Laboratory analyses

Particle size distribution was carried out using the pipette method as described by (Jackson 1969). According to Nelson (1982), the contents of calcium carbonate were measured by the calcimeter and gypsum were determined by precipitation with acetone. Electrical conductivity (EC) and exchangeable sodium percentage (ESP) were determined according to Richards (1954).

5- Soil classification

Soils were classified on the basis of the keys to Soil Taxonomy (USDA, 2014) till the level of soil family.

6- Land evaluation

Land evaluation for the purpose of agricultural land use was assessed according to Sys (1991) and Sys *et al* (1993) for the irrigated agriculture in arid and semi-arid regions. The conversion table as proposed by Sys *et al*. (1993) was used for olives and as defined in the guideline framework of FAO (1976). The modified conversion tables by Salah *et al*. (2001) for date palm and by Yossif *et al*. (2008) for jojoba were used.

7- Terminology and etymology contemplation

Terminology and etymology contemplation were traced using the Dictionary of Earth Science (Allaby, 2008) and the Latin English Dictionary (Smith and Lockwood, l996).

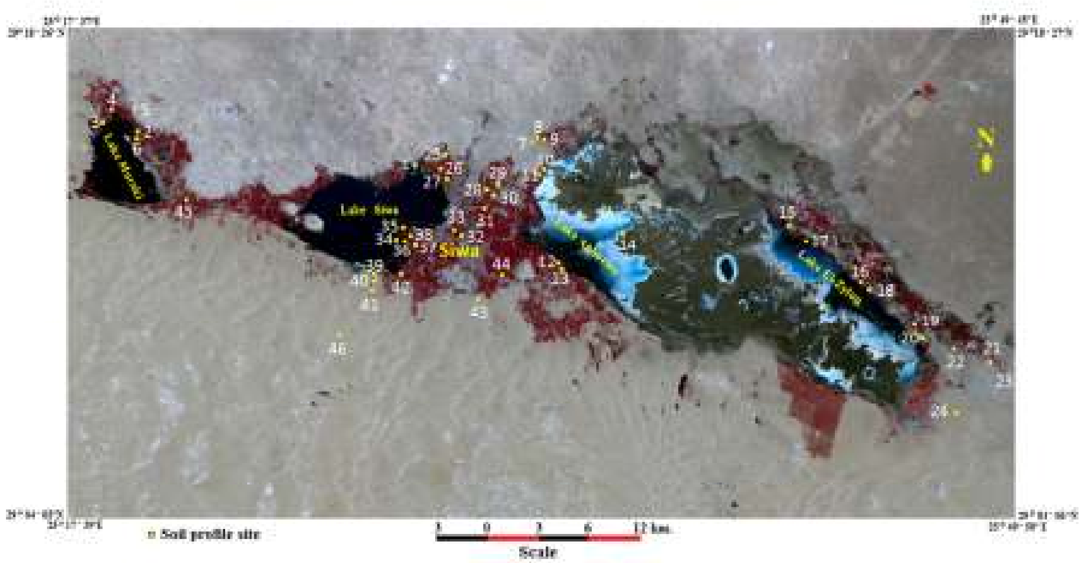

Figure 2. Allocated soil pedons within sub scene of TM8 acquired in 2018 path 180 row 40

RESULTS AND DISCUSSION

1- Monitoring the land degradation in the study area

Physiographic analysis and automated classification of pixel values were manipulated using the spectral signature of remote sensing data with reliable band combination. Afify *et al*. (2010) stated that using physiographic approach leads to a well understanding of landscape genesis. This approach help in setting up a reliable relationship between physiography and soils reflecting the different geomorphic processes (genetic approach). For monitoring the spatial changes of landscape features, the spectral signatures of remote sensing data acquired in the years 1986 and 2018 were processed as bench mark data and current status ones respectively. In both two projections, these spectral signatures permitted the discrimination of bare areas, cultivated areas and their growth status, water bodies, drainage conditions, settlements and roads. The physiographic units with other landscape features (settlements) in the two dates (listed in table 1 and delineated in figures 3) are described as follows:

a) Mesa

Mesas are high table lands (Spanish). They are isolated rocky structures, which are most probably remnants of former rocky landscape that were mostly dissected and eroded. They are standing up as isolated scattering rocky structures of different size. Mesas are mostly distributed within the landscape of pediplain as a result of their resistance to the former action of erosion process. They are covering 4931.13 hectares in the two dates of monitoring

b) Pediplain

The term pediplain is derived from the Latin words *pes,* which means "genitive case," The process through which pediplain is formed is called pediplanation under arid climate of rainfall during short duration in the region of the study area. The mechanical weathering act on soft rocks (r) resulting in thin soil strata of residual parent material as saprolite, which are underlying by that soft bedrock. The residual soils developed during the physiographic features evolution surrounding scattered isolated rocky structures (mesas). This pediplain occurred in different altitudes and are mostly extending over the northern part of the study area.

According to the evolution level of such landscape, pediplain is subdivided as follows:

b1) Pediplain of relatively high elevations

This pediplain has gently to very gently slope with gradients range from 3 to 5.5 %, which spatially decreased from 47327.31 to 40431.52 hectares, in the years 1986 and 2018, respectively.

b2) Pediplain of relatively low elevations (cultivated).

This pediplain has level to nearly level slopes with gradients range from 0.2 to 1.1 %, which increased from 4478.31 and 4916.19 hectares, in the years 1986 and 2018, respectively.

b3) Pediplain of relatively low elevations (waterlogged)

This pediplain is level deteriorated landscape by waterlogging with slope gradients range from 0.1 to 0.5 %. The waterlogged areas increased from 16184.21 to 16962.98 hectares, in the years 1986 and 2018, respectively.

c) Aeolian plain

Aeolian; etymology: Latin “aeolus” = god of the wind as an agent that act in eroding and depositing the sands. El-Baz (1998) reported that thise sand was born by water and sculpted by the wind relating theses sands to the fluvial erosion of the exposed Nubian Sandstone in the western desert and were transported northwards following the paleodrainage courses. During the dry climate, the wind mobilized the sand to be in dune forms. In the study area, aeolian plain that occurred by wind action in the open landscape, include loose sands of different elevations and slopes. Its parent material is laid down blankets of varying thickness. This aeolian plain is subdivided as follows:

c1) Aeolian plain of relatively high elevations

This aeolian plain is nearly level with slopes from 1.0 to 2.4% and decreased from 25313.20 17883.52 hectares, in the years 1986 and 2018, respectively.

c2) Aeolian plain of relatively low elevations (cultivated)

This aeolian plain is level with slope gradients from 0.2 to .4 % with an increasing of cultivated area from 537.78 to 3794.80 hectares, in the years 1986 and 2018, respectively.

c3) Aeolian plain of relatively low elevations (waterlogged)

This aeolian plain is level with slope gradients range from 0.2 to 0.5 %. This waterlogged area increased from 219.25 to 4346.15 hectares during the duration of monitoring.

d) Aeolian dunes

These aeolian dunes are extending in the southern part of the study area and that are dominantly undulating with slopes range from 5 to 8 % covering an area of 32420.60 in the year 1986, which decreased to 32397.10 hectares in the year 2018.

e) Ponded area (artificial lake)

These ponded areas are traditionally named in the study area as lakes. They are isolated extensive water bodies of frequent changes in their boundaries including spots in their outskirts. In these submerged areas, soils are covered by the access of free water during different frequencies in a closed depressed as a ponding process. These submerged areas represent the extreme case of land degradation in the study area as the soils are pounded under persistent internal free water covering an area. These bonded areas extent from 1986 to 2018 from 6700.48 to 12284.50 hectares.

2- Assessment of land degradation interference

The differences between the spatial distributions of physiographic features in the two years 1986 and 2018 are single differences that are not reflecting the multiple action on each other during the that duration. For allocating these multiple actin of land degradation, the polygons of lakes and waterlogged areas in the year 2018 were used for crossing all physiographic features in the year 1986. The process resulted in erasing areas from the crossed physiographic features in the year 1986 to be calculated as the same deteriorated level of the crossing ones. Although the cultivated areas increased from 1986 to 2018, part of them in the year 1986 were monitored as deteriorated ones in the year 2018. The extra bonded areas in 2018 covered 159.38, 80.56, 5296.6, 8.37, 6.70, and 34.37 hectares over pediplain, pediplain (cultivated), Pediplain (waterlogged), aeolian plain and aeolian plain (cultivated) respectively of the year 1986. Also waterlogged areas of 2018 erased 4917.61, 1273.21, 3887.37, 205.32 and 23.50 hectares from pediplain, pediplain (cultivated), aeolian plain, aeolian plain (cultivated) and aeolian dunes respectively. Collectively, 5585.97 and 10307.0 hectares have been bonded and waterlogged respectively as total area of land degradation of 15892.97 hectares (Table 2).

Table 1. Spatial changes of landscape features from 1986 to 2018

Physiographic units	Year of monitoring	
	1986	2018
	Area *(ha)	
Mesa	4931.13	4931.19
Pediplain	47327.31	40431.52
Pediplain (cultivated)	4478.31	4916.19
Pediplain (waterlogged)	16184.21	16962.98
Aeolian plain	25313.20	17883.52
Aeolian plain (cultivated)	537.78	3794.80
Aeolian plain (waterlogged)	219.25	4346.15
Aeolian dunes	32420.60	32397.10
Ponded areas (artificial lakes)	6700.48	12284.50
Other landscape features		
Settlements	908.90	1073.22
Total	139021.17	139021.17

***hectare = 2.38 feddans**

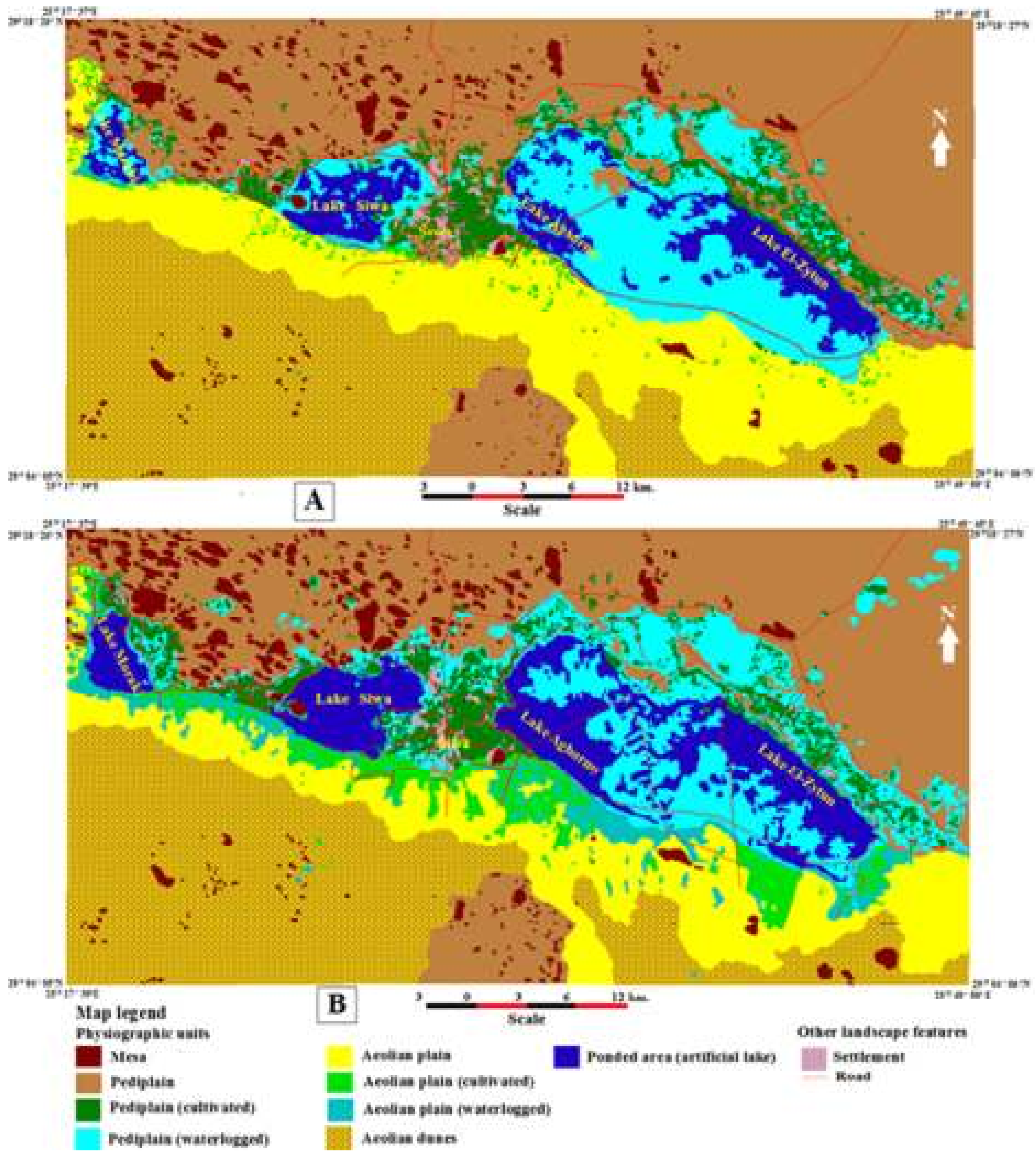

Figure 3. Catching up the physiographic features in the years 1986 (A) and 2018 (B)

Table 2. Multiple spatial land degradation in physiographic units from 1986 to 2018.

Deteriorated physiographic features of 1986	Levels and extends (area, ha) of land degradation in 2018		
	Ponded areas (artificial lakes)	Waterlogged area	Accumulated degradation levels
Pediplain	159.38	4917.61	5076.99
Pediplain (cultivated)	80.56	1273.21	1353.77
Pediplain (waterlogged)	5296.6	-	5296.6
Aeolian plain)	8.37	3887.37	3895.74
Aeolian plain (cultivated)	6.70	205.32	212.02
Aeolian plain (waterlogged)	34.37	-	34.37
Aeolian dunes	-	23.50	23.50
Total land degradation area	5585.97	10307.0	15892.97

3- Soil drainage conditions versus soil taxonomic units

Classification of soil drainage conditions is a clue for tracing the changes of spatial threat of land degradation (El Azab *et al.,* 2015). Drainage classes were mapped using unsupervised classification, which according to Afify *et al.* (2013) is more adequate than supervised one for the old arable land in Egypt of small land tenures. The drainage classes can be revised using local reference level of the interpreter for combining features or splitting classes for setting up the legend. In the sdudy area, drainage condition classes based on: i) Observing the free water using auger hole; ii) Identification of redoximorphic features as strong gleying when stagnant water preserve iron in reduced state. Associated color of the strong gleying were determined within the notations of GLEY1 and GLEY2, which reflect a deteriorated drainage in certain stratum. This attribute was designated within the master horizons as the lowercase letter (g). The defined soil drainage classes and associated soil characteristics are shown in Table 3.

Table 3. The required soil physical and chemical attributes for assessing land degradation and land evaluation

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution (%)			Modified Texture class	CaCO3 (g/kg)	CaSO4.2 H2O (g/kg)	EC (dS/m)	ESP
						sand	silt	clay					
Excessively drained	Aeolian plain	23	0-20	A	-	98.3	1.1	0.6	S	108	9	25.2	10.9
			20-150	C	-	96.7	2	1.3	S	97	5	20.4	13.1
		24	0-30	A	-	95.9	3.2	0.9	S	134	8	14.7	12.2
			30-150	C	-	98.7	0.6	0.7	S	131	6	10.6	11.8
		41	0-30	A	-	98.1	1.1	0.8	S	71	7	4.9	12.3
			30-65	C	-	98.6	0.8	0.6	S	67	6	15.6	11.0
	Aeolian dunes	46	0-30	A	-	94.5	2.6	2.9	S	109	3	4.5	6.9
			30-50	C1	-	96.2	2.3	1.5	S	102	4	15.0	5.6
			50-100	C2	-	96.8	2.3	0.9	S	118	3	10.2	6.8
Well drained	Pediplain (Cultivated)	4	0-35	Akp	10	72	18.2	9.7	SGSL	82	1	3.9	13.0
			35-75	Bk1	5	69	9.8	21.2	SCL	153	16	5.1	14.2
			75-110	Bk2	5	51.4	18.9	29.7	SCL	108	5	5.6	10.1
			110-125	C	10	50.3	26.6	23.1	SGSCL	154	6	8.6	15.4
			125-	Water table									
		31	0-30	Akp	10	44.7	36.7	18.6	SGSL	152	21	3..7	11.5
			30-60	Bk1	10	55.2	20.9	34.1	SGSCL	185	25	4.1	14.9
			60-100	Bk2	5	49.4	22.2	28.4	SCL	162	7	5.2	9.7
			100-120	C	10	57.5	4.7	37.8	SGSCL	216	7	7.5	22.2
			120-	Water table									

A ,B, C and r = Master hori horizons; g (reflects the color notations of GLEY1 and GLEY2), k, p, y and z = diagnostic horizons; vv = volume of void-space.; G=gravely, SG= slightly gravely; S= sand, LS= loamy sand, SL=sandy loam SCL= sandy clay loam; EC (dS/m) Electrical conductivity in decisiemens. ESP = Exchangeable sodium percentage.

Table 3 Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution (%)			Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4$.2 H_2O (g/kg)	ECe (dS/m)	ESP
						sand	silt	clay					
Well drained	Pediplain (cultivated)	25	0-30	Ap	5	94.1	3.5	2.4	S	95	8	3.3	3.6
			30-65	C	5	85.3	12.4	2.3	LS	53	4	4.5	14.9
			65-125	2BCk	10	71.1	7.81	21	SGSCL	154	3	6.1	14.2
			125-	Water table									
		27	0-30	Ap	-	94.3	2.6	3.1	S	96	3	3.1	12.1
			30-60	C	-	95.3	2.4	2.3	S	96	8	2.5	10.2
			60-120	2BCk	5	50.3	22.3	27.4	SCL	205	5	5.5	14.8
			120-	Water table									
	Aeolian dunes (cultivated)	45	0-30	A	-	95.3	3.2	1.5	S	82	12	.3.2	5.2
			30-100	C	-	94.9	2.3	2.8	S	99	4	2.9	7.5
			100-120	Cg	-	96.4	2.1	1.5	S	109	3	2.5	6.7
			120--	Water table									
Moderately well drained	Pediplain	5	0-50	ABkz	15	61.2	24.8	14	GSL	498	10	96.3	97.8
			50-120	BCz	25	42.3	28.5	29.2	GSCL	204	4	30.1	30.93
			120-	r	Paralithic contact of soft rock (shale)								
		7	0-20	Agkz	10	50.2	30.3	19.5	SGSL	418	29	153.3	81.2
			20-45	Ck	20	46.5	3.1	50.4	GSC	466	3	77.5	96.7
			45-	r	Paralithic contact of soft rock (shale)								
		20	0-30	Akz	10	70.9	16.6	12.5	SGSL	176	63	126.8	86.4
			30-52	Bkz	15	73.5	16.7	9.8	GSL	273	106	100.6	80.4
			52-	r	Paralithic contact of soft rock (shale)								

Table 3. Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size istribution(%)			Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4$.2 H_2O (g/kg)	ECe (dS/m)	ESP
						sand	silt	clay					
Moderately well drained	Pediplain	21	0-30	Akz	10	74.1	10.6	15.3	SGSL	168	25	138.5	85.1
			30-55	Bkz	15	73.5	16.7	9.8	GSL	273	106	114.5	80.4
			55-	r	Paralithic contact of soft rock (shale								
	Pediplain (cultivated)	2	0-30	ACp	5	86.6	2.7	10.7	LS	105	29	7.2	22.4
			30-50	2Bk1	15	73.8	15.5	10.7	GSL	151	1	5.6	20.4
			50-75	2Bk2	5	68.7	20.5	10.8	SL	187	3	5.4	26.6
			75-95	2Bgk	10	46.5	23.5	30	SGSCL	159	4	7.6	22.3
			95-	Water table									
		9	0-30	ACp	5	85.8	5.7	8.5	LS	152	7	4.5	10.5
			30-75	2Bk1	5	79.2	10.3	10.5	SL	107	9	6.2	16.9
			75-100	2Bgk	10	76.3	12.7	11	SGSL	102	13	5.8	16.0
			100-	Water table									
		10	0-25	ACp	-	89.8	5.6	4.6	S	154	24	6.2	12.8
			25-65	C	-	92.9	1.4	5.7	S	135	1	5.7	14.9
			65-95	2Bgk2	10	78.8	10.8	10.4	SGSL	162	24	6.4	18.2
			95--	Water table									
		12	0-30	Ak	10	74.3	15.4	10.3	SGSL	144	32	4.5	33.7
			30-60	Bk	15	66	19.8	14.2	GSL	85	15	4.1	15.4
			60-85	Bgk	15	65.9	19.3	14.8	GSL	168	1	7.9	15.7
			85-	Water table									

Table 3. Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution(%)			Modified Texture class	$CaCO_3$ g/kg	$CaSO_4 2H_2O$ (g/kg)	ECe (dS/m)	ESP
						sand	silt	clay					
Moderately well drained	Pediplain (cultivated)	22	0-30	ACp	5	87.9	6.5	5.6	LS	152	15	7.0	15.4
			30-65	2Bk	5	69	18.6	12.4	SL	209	49	6.1	9.6
			65-85	2Bkg	5	78.2	3.5	18.3	SL	141	14	5.8	9.2
			85-						Water table				
		26	0-30	Akp	5	79.6	2.9	17.5	SL	186	29	9.6	10.5
			30-75	Bk	10	70.5	16.9	12.6	SGSL	13 6	44	8.4	14.7
			75-95	Bgk	10	54.1	19.2	26.7	SGSCL	142	29	10.2	12.3
			95-						Water table				
		29	0-30	Akp	5	78.7	9.8	11.5	SL	112	23	1.7	11.85
			30-80	Bk	10	78.9	9.6	11.5	SGSL	147	29	8.0	16.69
			80-95	Bgk	15	81.3	2.4	16.3	GSL	172	27	9.2	20.4
			95--						Water table				
		30	0-30	ACp	5	92.4	6.3	1.3	S	102	9	2.8	84.6
			30-65	2Bk	5	71.2	19.3	9.5	SL	114	24	7.8	24.2
			65-100	2Bgk	10	71.4	9.3	19.3	SGSL	151	8	8.20	31.8
			100-						Water table				
		3	0-25	ACp	5	86.3	5.6	8.1	LS	126	7	8.5	17.9
			25-75	Bk	15	64.3	10.5	25.2	GSCL	209	9	5.7	15.4
			75-95	Bgk	10	63.3	8.5	28.2	SGSCL	159	7	6.4	14.5
			95-						Water table				

Table 3. Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution(%)			Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4 2H_2O$ (g/kg)	ECe (dS/m)	ESP
						sand	silt	clay					
Moderately well drained	Pediplain (cultivated)	16	0-35	Ak	5	61.6	22.6	15.8	SL	122	1.8	9.1	15.8
			35-70	Bk	10	47.5	24.2	28.3	SGSCL	181	33	3.50	6.8
			70-85	Cgk	10	50.3	19.3	30.4	SGSCL	135	3	3.48	5.9
			85-										
		37	0-30	Agkz	5	72.9	18.9	8.2	SL	144	2	4.1	9.1
			30-55	Bk	10	67.6	9.8	22.6	SGSCL	257	2	5.2	17.3
			55-100	Bgky	10	73.2	2.6	24.2	SGSCL	245	57	8.6	13.8
			100-						Water table				
		32	0-30	Akp	5	72.7	20.9	6.4	SL	145	2	2.1	23.7
			30-55	2Bk	10	71.4	4.3	24.3	SGSCL	157	24	2.7	3.2
			55-80	2Bgy	15	72.9	4.8	22.3	GSCL	68	99	10.9	12.9
			80-						Water table				
		33	0-30	ACp	5	89.5	4.2	6.3	LS	85	22	7.9	9.99
			30-60	2Bky	10	78.2	11.2	10.6	SGSL	146	98	4.7	11.6
			60-90	2Bgky	15	69.3	10.2	20.5	GSCL	96	75	9.3	14.2
			90-						Water table				
	Aeolian plain (cultivated)	42	0-30	Ap	-	96	2.2	1.8	S	53	17	5.13	14.3
			30-60	C	-	97.9	1.4	0.7	S	63	2	2.90	9.5
			60-100	Cg	-	95.8	2.3	1.9	S	64	3	2.5	10.2
			100-						Water table				

Table 3. Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution(%)			Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4 2H_2O$ (g/kg)	ECe (dS/m)	ESP
						sand	silt	clay					
Moderately well drained	Aeolian plain (cultivated)	44	0-30	A	-	94.3	4.2	1.5	S	102	4	1.6	4.2
			30-65	C	-	96.9	2.2	0.9	S	99	16	3.4	7.7
			65-95	Cg	-	94.5	2.5	2.9	S	86	21	6.7	8.4
			95-						Water table				
Poorly drained	Pediplain (waterlogged)	6	0-30	Akz	10	80	6.7	13.2	SGSL	242	35	45.0	29.8
			30-105	Bgkz	10	58.9	11.6	29.5	SGSCL	150	63	20.3	160.7
			105-	r					Wet paralithic contact of soft rock (shale)				
		8	0-25	ABkz	10	73.5	14.7	11.8	SGSL	331	45	125.6	50.7
			25-60	Bgkz1	10	56.7	12.5	30.8	SGSCL	225	14	132.6	75.2
			60-75	Bgkz2	5	66.8	11.9	21.3	SCL	418	5	19.5	23.8
			75-	r					Wet paralithic contact of soft rock (shale)				
		15	0-25	Akz	10	54.1	27.5	18.4	SGSL	84	48	108.3	95.4
			25-55	Bgz	10	45.6	26.7	27.7	SGSCL	24	47	70.3	40.5
			55-65	Bgkz	15	71.4	3.3	25.3	GSCL	112	36	47.3	35.4
			65-	r					Wet paralithic contact of soft rock (shale)				
		28	0-30	Akz	5	67.5	20.3	12.2	SL	105	24	٨٦.٦	63.8
			30-75	Bgkyz1	5	75.3	15.5	9.2	SL	112	41	٥٣.٠	67.6
			75-105	Bgkyz2	10	73.7	15.9	10.4	SGSL	60	46	٢٠.٦	25.3
			105-	r					Wet paralithic contact of soft rock (shale)				

Table 3. Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution(%) sand	silt	clay	Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4.2H_2O$ (g/kg)	ECe (dS/m)	ESP
Poorly drained	Pediplain (waterlogged)	35	0-30	Agkz	5	72.3	6.4	21.3	SCL	391	3	30.5	27.6
			30-50	Bgk	10	69.4	11.9	18.7	SGSL	383	8	18.6	16.1
			55-95	Bgk	10	74	6.7	19.3	SGSL	327	7	3.19	22.3
			95-	r		Wet paralithic contact of soft rock (shale)							
		19	0-30	Akz	10	53.5	36.1	10.4	SGSL	402	2	٤٤.٨	33.4
			30-60	Bgkz	5	72.3	20.2	7.5	SL	502	3	33.3	38.6
			60-110	Bgk	10	66.2	20.4	13.4	SGSL	144	9	٢٧.٢	32.8
			110-	r		Wet paralithic contact of soft rock (shale)							
	Aeolian plain (waterlogged)	40	0-30	Az	-	93.5	5.6	0.9	S	55	26	٥٥.٨٠	85.7
			30-75	Bgy	-	88.1	9.7	2.2	S	38	60	١٢.٧٥	21.4
			75-			Water table							
Very poorly drained	Pediplain (waterlogged)	1	0-15	Agz	5	78.9	10.4	10.7	SL	168	66	١٤٣.٤	61.9
			15–40	Bgkz	5	86.7	6.5	6.8	LS	337	7	١١٤.٥	69.2
			40-	r		Wet paralithic contact of soft rock (shale)							
		11	0-15	ACgz	5	96.9	1.8	1.3	S	126	94	١٥٥.٥	99.6
			15-35	2Bgz	5	79.3	10.3	10.4	SL	257	18	32.0	96.7
			35-	2r		Wet paralithic contact of soft rock (shale)							
		13	0-30	ABgz	15	53.9	26.7	19.4	GSL	24	56	١٠٦.٣	98.2
			30-	r		Wet paralithic contact of soft rock (shale)							
		14	0-35	ABgzy	10	58	19.7	22.3	SGSL	16	74	١٥٨.٣	67.8
			35-	r		Wet paralithic contact of soft rock (shale)							

Table 3 Contenue

Soil drainage class	Physiographic unit	Profile No.	Depth (cm)	Horizon	Gravel % (vv)	Particle size distribution(%) sand	silt	clay	Modified Texture class	$CaCO_3$ (g/kg)	$CaSO_4.2H_2O$ (g/kg)	ECe (dS/m)	ESP
Very poorly drained	Pediplain (waterlogged)	18	0-30	ABgkyz	10	42.4	43.1	14.5	SGSL	84	73	١٠٤.٥	78.1
			30-49	Bgkgz	5	63.5	19.7	16.8	SL	116	11	٦٣.٧	43.1
			49-	r		Wet paralithic contact of soft rock (shale)							
		17	0-15	ABgyz	5	45.4	38.3	16.3	SL	56	10	١٦٨.٥	99.3
			15-30	Bgkz	5	20.1	46.2	33.7	CL	225	58	١١٩.٧	74.8
			30-	r									
		34	0-15	Agyz	5	79.8	12.6	7.6	LS	74	113	١١٦.٦	251.6
			15-35	Bgkz	10	47.8	19.4	32.8	SGSCL	326	23	٥٨.٦	47.3
			35-	r		Wet paralithic contact of soft rock (shale)							
		38	0-20	Agzy	5	75.4	10.7	13.9	SL	24	75	١٩٥.٠	76.4
			20-45	Bgyz	10	57.5	17.8	24.7	SGSCL	26	27	١٣٠.٥	16.7
			45-	r		Wet paralithic contact of soft rock (shale)							
		36	0-20	ABgkz	10	74.1	13.6	12.2	SGSL	361	13	٣٦.٩	27.5
				r		Wet paralithic contact of soft rock (shale)							
	Aeolian plain (waterlogged)	39	0-30	Agz	-	88.9	7.6	3.5	S	21	26	١١٩.٥	102.
			30-45	Bgy	-	88.6	6.2	5.2	S	42	85	١٠.٣	15.1
			45-			Water table							
		43	0-25	Agz	-	93.5	4.7	1.8	S	97	61	٣٥.٧	79.
			25-			Water table							

Soil drainage classes with their associated soil taxonomic classes in certain physiographic units are described as follows:

a) Excessively drained soils

These excessively drained soils occurred in the southern and western parts of the study area representing the aeolian plain and aeolian dunes of non-cultivated land. In these soils, the occurrence of internal free water is very deep (>1.5 m). The soils are sandy soils (coarse-textured) representing the virgin parent material "C" having dry soil control section in all parts. The soils have thermic soil temperature regime and an aridic soil moisture regime. They are Typic Torripsamments, mixed (calcareous) as represented by soil profiles 23, 24, 41, and 46.

b) Well drained soils

Well drained soils are distributed within the cultivated land having managed surface layer "Ap" in different physiographic units in the study area. The soils have deep (1.0 to 1.5 m) internal free water occurrence and its wetness does not inhibit growth of roots for significant periods during most growing seasons. They are deep to, redoximorphic features related to wetness and occurred in pediplain having calcic horizon "k" within 100 cm of the soil surface. The calcium carbonate contents are from 82 to 216 g/kg soil and the soil control section is denominated by sandy clay loam texture class (fine loamy). The soils are classified as Typic Haplocalcids, fine loamy, mixed (profiles 4 and 31). These soils have layers of 2BCk are locally and artificially covered by transported aeolian sands "C" fitting the taxonomic class of Typic Haplocalcids, sandy over fine loamy, mixed (profiles 25, and 27). In the case of aeolian plain, its recent soils "C" have dry moisture control section in all parts with thermic soil temperature regime and an aridic soil moisture regime that borders on xeric. They are classified as Xeric Torripsamments, mixed (calcareous (profile 45).

c) Moderately well drained soils

Moderately well drained soils are partly cultivated areas. In these soils, internal free water occurrence is moderately deep (50 cm to 1 m) and the soils are wet within the root zone affecting on many of mesophytic plants. Soils have a layer within the upper 1 meter of fine texture that can reduces the value of the hydraulic conductivity. Soils in pediplain, have layers of salic horizon. (30.1 to 153.3 ds/m. "z"), which associates with calcic one "k" calcium carbonate contents are from 204 to 498 g/kg soil in surface "Akz" and sub-surface "Bkz". Soil control section is denominated by sandy loam texture class (coarse loamy) including more than 40 percent by weight carbonates as $CaCO_3$ plus gypsum (carbonatic) fitting the taxonomic unit of Calcic Haplosalids, coarse loamy, carbonatic (soil profiles 5, and 7). These soils are locally not carbonatic having sub surface gypsic horizon "y" fitting the taxonomic unit of Gypsic Haplosalids, coarse loamy, mixed (profiles 20 and 21). In these soils, salic and gypsic horizons inherited from weathered soft bedrock "r" bellow deep to moderately deep strata.

Soils of cultivated pediplain have calcic horizon "k" (calcium carbonate is from 85 to 209 g/kg) soil. soils are saturated with water " Bg" in one layer within 100 cm of their surface (Aquic) The control section is dominated by sandy loam (coarse loamy). The soils are classified as Aquic Haplocalcids, coarse loamy, mixed (soil profiles 2, 9, 10, 12, 22, 26, 29 and 30). These soils are locally fine loamy to be classified as Aquic Haplocalcids, fine loamy, mixed (soil profiles 3, 16 and 37) but become Typic Calcigypsids, fine loamy, mixed when the gypsic horizon "By" developed (soil profiles 32 and 33). Moderately well drained soils in aeolian plain have recent parent material "C" with managed surface layer "Ap". They are saturated with water in the depth from 60 to 100 cm. from the soil surface fitting the taxonomic unit of Oxyaquic Torripsamments, mixed (calcareous), which were represent by profiles 42 and 44).

d) Poorly drained soils (waterlogged)

These poorly drained soils in pediplain and aeolian one having wet layers at shallow depths (25 cm to 50 cm) with internal free water is persistent near the soil surface long enough during the growing season. In this current status most mesophytic plants cannot be grown. The dominant soils have salic horizon "z" of salinity range from 19.5 to 132.6 dS/m and sub-surface saturation with stagnant water preserving a reduced state of strong gleying "g". Calcic horizon "Bk" also developed with calcium carbonate contents from 84 to 382 g/kg soil. These soils are categorized as Calcic Aquisalids, fine loamy, mixed (soil profiles 6, 8 and 15). These soils are locally dominated by sandy loams (coarse loamy) to be Calcic Aquisalids, coarse loamy, mixed (soil profiles 28 and 35). Within this locality, some strata have more than 40 percent by weight carbonates plus gypsum to be Calcic Aquisalids, coarse loamy, carbonatic (soil profile 19). In aeolian plain of recent sands, salic horizon "z" developed in the soil surface (55.8 dS/m). Gypsic horizon "y" including 6.0 g/kg soil developed in soil sub-surface associated with strong gleying "gy" fitting the taxonomic unit of Typic Aquisalids, sandy, mixed (soil profile 40)

e) Very poorly drained soils (waterlogged)

In these soils free water stagnate near soil surface with very shallow internal free water (<25 cm) inhibiting the growth of most mesophytic plants. The soils occurred in the relatively depressed pediplain with dominant soils having salic "z" of 32.0 to 158.3 ds/m and gypsic "y" horizons with gypsum contents range from 56 to 94 g/kg soil. (Gypsic Aquisalids, coarse loamy, mixed represented by soil profiles 1, 11, 13, 14 and 18. These soils are locally fine loamy fitting the taxonomic class of Gypsic Aquisalids, fine loamy, mixed (soil profiles 17, 34 and 38). In another soil inclusion, calcic horizon "k" replaced the gypsic horizon "y" so the soils are classified as Calcic Aquisalids, coarse loamy (soil profile 36). In aeolian plain, salic "z" with salinity of 35.7 to 119.5 dS/m and gypsic "y" horizons with gypsum contents of 6.1 to 8.5 g/kg soil were developed in recent sands associated with strong gleying "gyz" realizing taxonomic unit of Gypsic Aquisalids, sandy, mixed (soil profiles 39 and 43). Those defined soil drainage classes with their associated physiographic units and soil taxonomic units are listed in Table 4 and mapped in figure 3.

Table 4. Soil drainage classes and their associated soil taxonomic units

Soil drainage class	Physiographic unit	*Soil Taxonomic unit
Excessively drained	Aeolian plain Aeolian dunes	*Typic Torripsamments, mixed (calcareous).*
Well drained	Pediplain (Cultivated)	# *Typic Haplocalcids, fine loamy, mixed.* *Typic Haplocalcids sandy over fine loamy, mixed.*
	Aeolian plain (Cultivated)	*Xeric Torripsamments, mixed (calcareous).*
Moderately well drained	Pediplain	# *Calcic Haplosalids, coarse loamy, carbonatic.* *Gypsic Haplosalids, course loamy, mixed.*
	Pediplain (cultivated)	# *Aquic Haplocalcids, coarse loamy, mixed* *Aquic Haplocalcids, fine loamy, mixed.* *Typic Calcigypsids, fine loamy, mixed.*
	Aeolian plain (cultivated)	*Oxyaquic Torripsamments, mixed (calcareous).*
Poorly drained	Pediplain (waterlogged)	# *Calcic Aquisalids, fine loamy, mixed.* *Calcic Aquisalids, coarse loamy, mixed.* *Calcic Aquisalids, coarse loamy, carbonatic.*
	Aeolian plain(waterlogged)	*Typic Aquisalids, sandy, mixed.*
Very poorly drained	Pediplain (waterlogged)	# *Gypsic Aquisalids, coarse loamy, mixed* *Gypsic Aquisalids, fine loamy, mixed* *Calcic Aquisalids, coarse loamy, mixed*
	Aeolian plain (waterlogged)	*Gypsic Aquisalids, sandy, mixed*

***All soil taxonomic units are of *thermic* temperature regime # Dominant soil taxonomic class.**

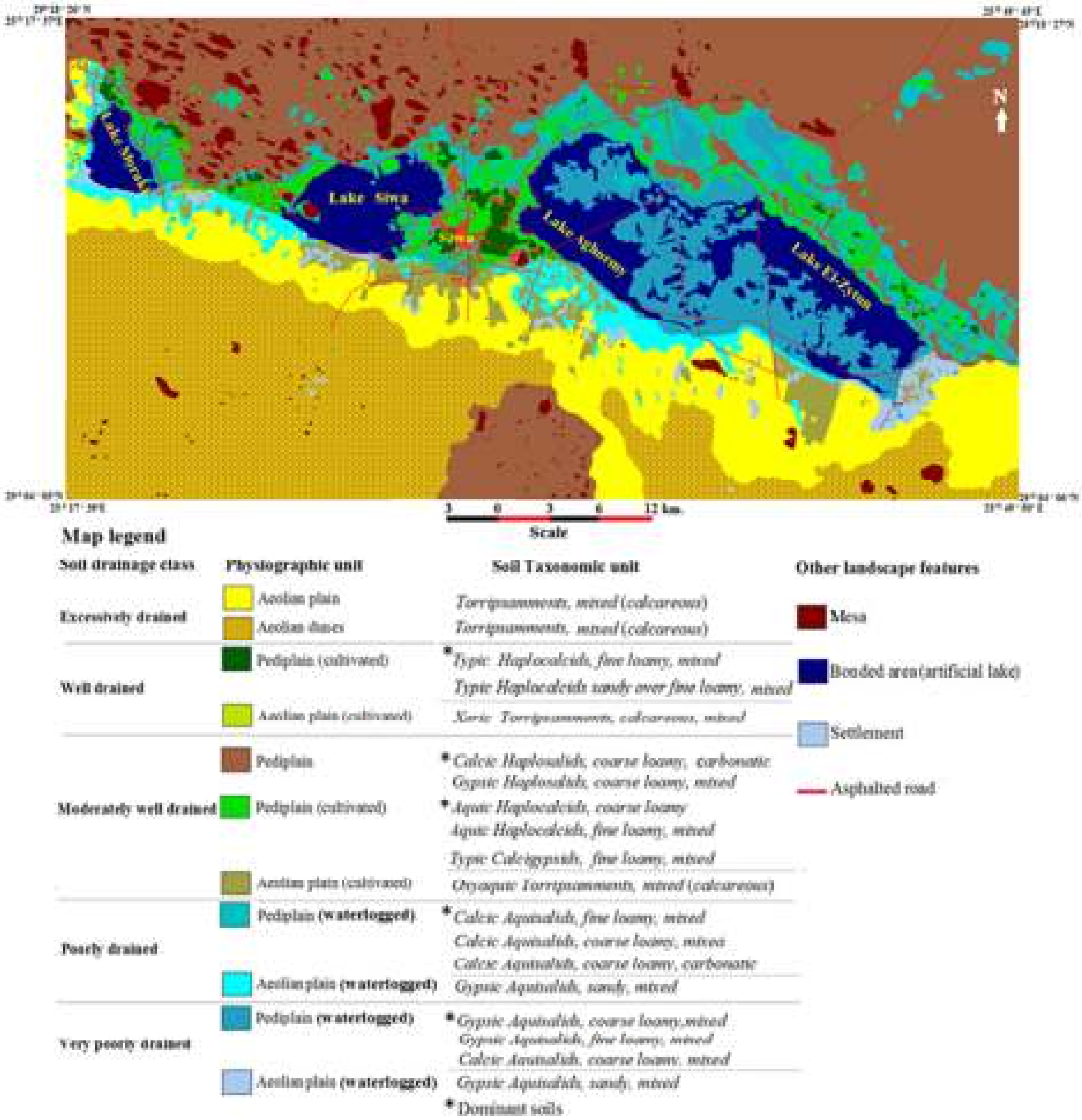

Figure 4. Soil drainage classes as associated of physiographic features soil taxonomic units

4- Land degradation evolution in the study area

Land degradation process in the study area has been activated by man-made and natural reasons. The cultivation is managed using surface irrigation with over pumping. According to the Ministry of Irrigation and Water Resources in Egypt (2006), in Siwa Oasis, the annual discharge of irrigation water from the aquifers is about 255 million cubic meters. About 222 million cubic meters are lost as evapotranspiration, while the remainder goes to the lakes of Siwa Oasis. In the study area, these informal water practices exaggerates the land degradation as managed on inferior soil characteristics in the prevailing physiographic features. The landscape of Siwa Oasis and its outskirts seem as endclosed drainage basin fitting the term of playa, which means strand (Spanish). Wthin this playa, sediments are mostly located in the shelter of the relatively lower areas compared with the surounding landscapes. The slopes are oriented in descending directions via converted drainage flows to the midle part of this playa in different depressed areas without outlet from zero sea level to belw than -25 m below sea level. Pediplain that is relatively depressed have salt affected areas and retreated to be locally ponded. The extents of land degradation are proportionally affected according to their different relative elevations as well as their sites within the slope directions (figure 4). The residual parent material have limited soil stratum underlain by impermeable soft rocks “r” or of compacted layers that stagnate shallow salinized water table. This perched water table is seeped with the slope directions. In the cultivated pediplain, many areas are covered with a surface mantle of human-transported aeolian sands that are more than 50 cm or more thick. These sands has been moved horizontally on pedons of finer soil texture as sandy clay loam or sandy loam (Table 1). The drainable irrigated water moved vertically from the coarser texture to stagnant over the finer ones accelerating waterlogging and salinization process.

In aeolian plain, irrigation water is draining vertically within sandy strata but partly is seeped following the descending slopes to the depressed areas. Accordingly, the soils in areas that are relatively high or in outside the cultivated zones are not waterlogged, while those of relatively low elevations and surrounding by the cultivated areas were affected by the fluctuations of waterlogging or submerged by the drainable water to be a bonded area. These man-made and natural elements are acting as integrated elements within sensitive hydrogeological system in an isolated depression within a region of an intense aridity. These elements resulted an extra extension of land degradation as represented in a multiple changeable classes of soil drainage conditions and salt accumulation in the waterlogged areas were accelerated. On other hand the lack of maintenance of drainage channels led to the growth of reeds, preventing the flow of drainage water. Continuing these reasons of land degradation, drainage condition will be most probably deteriorated on the long run and no longer cope with the increased seepage. The deterioration will cover large areas to be bonded or waterlogged.

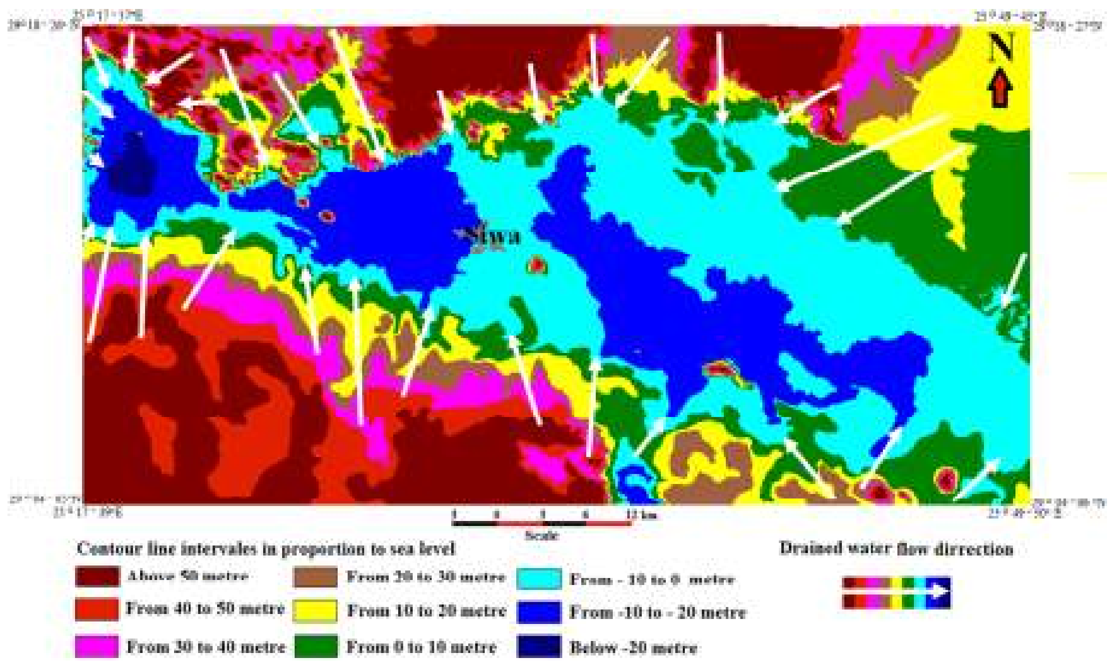

Figure 5. Contour line intervals and most active flow directions of drained water in the study area

5- Land evaluation for specific Land Utilization Types (LUTs)

a) Selection of LUTs

Land suitability that was assessed for current (LUTs) and proposed introduced one based on modifying surface irrigation to be a drip one. They are described as follows:

a1) Modified LUTs of current distinctive repository

These LUTs varieties are date palm and olives as a vital agrobiodiversities of adapted ancestral agricultural management. They have been grown during selection of natural circumstances and human interest of careful practices. Gepts *et al.* (2012) defined the agrobiodiversity as variability of plant maintained by human societies and has leverage against the changes of climatic and socioeconomic elements as well as the effects of emerging new diseases.

- Date palm (*Phoenix dactylifera L.*)

This agrobiodiversity is highly required for food and livelihood security in Siwa oasis. According to Battesti *et al* (2018) date palm in Siwa includes ethno varieties. The seedling date palms seem to be a true gene pool for the date palm farmers and are possibly part of the original pool for the current diversity of cultivars. Local farmers are attuned to phenotypic traits in their categorization. They are fully acknowledge that phenotype is shaped by inheritance from both male and female plants and by soil and climatic conditions.

- Olive tree (*Olea europaea L.)*

This LUT in Siwa is in complimentary geographic extension with the recommended olive belt cultivation by Afify (2009) within the paleodrainage delta in the Western Desert of Egypt. This proposed olive belt considered the geographic area of origin that make a significant effect on the qualitative and sensory characteristics of olive oils as native in Siwa or in nationwide of Egypt. Olive oils produced in Siwa Oasis contains higher percentage content of oleic acid comparing that produced in Giza area. (Cinzia *et al.*, 2011). This virgin olive oil has more monounsaturated fatty acids than other olive oils. (Bouaziz *et al.*, 2010 and Shales-Campos *et al.,* 2013). Phenolic compound have pharmacological activities as antioxidant, anti-inflammatory, anti-atherogenic, anti-cancer activities, antimicrobial activity and antiviral activity. (Omar, 2010 and World's Healthiest Foods, 2018).

a2) Proposed LUT of Jojoba shrub [*Simmondsia chinensis* (Link) Schneider]

Jojoba shrub [Simmondsia chinensis (Link) Schneider] is proposed LUT to be cultivated under drip irrigation. This LUT can be easily adapted with the drought of the study area. Also can tolerates the current land degradation of soil salinity and alkalinity and can be grown in sandy soil of marginal fertility. This proposed LUT is promising unique oil crop, which according to Aed Adam (2015) it contain a liquid wax of economic importance in industry as a machine lubricant and cosmetics. According to Abdel-Mageed *et al.* (2016) this oil has high-quality as medical and industrial products. Al-Widyan (2010) added that jojoba oil and its cake hold real promise as alternative energy sources. Using jojoba cake for bio-gasification resulted in a yield of about 600 ml biogas per 400 g of jojoba cake.

b) Land evaluation assessment

Land qualities were matched with requirements of each LUT for setting up the land suitability sub-class to be valid for these irrigated crops in such arid region. The suitability was mapped considering the dominated soil taxonomic units in certain physiographic unit. The suitability was calculated considering the ratings of CaCO3 (e), drainage (d), coarse fragments(g), sodicity (n), depth (p), salinity (s), slope (t), texture (x) and gypsum (y). The land suitability was categorized as suitability orders of suitable (S) and not suitable (N). Classes are highly suitable (S1) moderately suitable (S2) and marginally suitable (S3), currently not suitable (N1) and potentially not suitable (N2). The sub-classes are defined by lowercase-letters concerning the effective limitations.

b1) Current land suitability

Land suitability sub classes in Table 5 indicate that the main limiting factors in the study area are calcareousness, depth, drainage condition, salinity and sodicity, which are partly inhibiting the growth of some crops. Excessively drained soils (in aeolian plain) are S3sx for date palm and S3s for olives, while are S2m for Jojoba. Soils of the same drainage class (in aeolian dunes) are S3stx, S3st and S2m for date palm, olives and Jojoba respectively. Well drained soils in cultivated lands are S2n and for date palm and S2m for olives, while are S1 for Jojoba. Moderately well drained soils in cultivated pediplain are S3c, S3d and S2m for date palm, olives and Jojoba respectively. Soils of the same drainage class in aeolian plain) are S3x, S2m and S1 for date palm, olives and Jojoba respectively. In the non-cultivated pediplain, the soil limitations reduced the suitability to N1cnps, N1nsp and N1nps for date palm, olives and Jojoba respectively. Poorly drained and very poorly drained soils are N1cdnps for date palm, while are N1dnsp for olives and Jojoba. In aeolian plain, poorly drained and very poorly drained soils are N1dnsx for date palm, while are N1dns for olives and Jojoba. Mesas of rocky structures are N2p for all LUTs.

Table 5. Current land suitability for LUTs before soil improvement

Soil drainage class	Physiographic unit	Land suitability sub class		
		Traditional crops		Proposed crop
		Date palm	Olives	Jojoba
Excessively well drained	Aeolian plain	S3sx	S3s	S2m
	Aeolian dunes	S3stx	S3st	S2m
Well drained	Pediplain cultivated)	S2n	S2m	S1
	Aeolian plain (cultivated)	S2x	S2m	S1
Moderately well drained	Pediplain (cultivated)	S3c	S3d	S2m
	Pediplain	N1cnps	N1nsp	N1nps
	Aeolian plain (cultivated)	S3x	S2m	S1
Poorly drained	Pediplain	N1cdnps	N1dnsp	N1dnps
	Aeolian plain	N1dnsx	N1dns	N1dns
Very poorly drained	Pediplain	N1cdnps	N1dnsp	N1dnps
	Aeolian plain	N1dnsx	N1dns	N1dns
-	Mesa	N2	N2	N2

Highly suitable (S1), moderately suitable (S2) and marginally suitable (S3), currently not suitable (N1) and potentially not suitable (N2). Ratings are CaCO3 (c), drainage (d), sodicity (n), salinity (s), depth (p), slope (t), texture (x) and minor limitations (m).

b2) Potential land suitability

The current land suitability for certain cropping patterns can be more profitable and applicable after executing specified major land improvements (Table 6 and figure 5). These improvements depend on the holders that have high capital intensities. If the capital intensity is low, large land tenures can be managed by farmers for developing the current land attributes. Recommended major improvements in the study area concern soil drainage condition, salinity and sodicity. Accordingly, soils in aeolian plain of excessively well drained (E), well drained (W), moderately well drained (MW), poorly drained (P) and very poorly drained (VP) will improved to be S2x for date palm, S1 for olives and Jojoba. In cultivated pediplain, soils that are W and E will be S1/ S2c (partly S2c) for date palm, while to be S1 for olives and Jojoba. In aeolian dunes of E, soils will be S3tx for date palm, while will be S2t for olives and Jojoba. Pediplain of P, soils will still not suitable (N2cp) for date palm, while will be S2p for olives and Jojoba. Pediplain of MW, soils will still not suitable (N2cp) for date palm but will be N2p / S3p (partly S3p) for olive and N2p / S2p/ (partly S2p) for Jojoba. In pediplain, soils that are VP, will still not suitable as N2cp for date palm and N2p for both olives and Jojoba. Mesas as rocky structures will not be improved (N2) for all LUTs.

Evaluating the physiographic unit for these certain LUTs concluded that modifying the irrigation practices to be drip irrigation will protect a unique cultural landscape in Egypt. Sustainability of growing an important crops of specific quality for high economical production is highly required. Potentially, about 8710.99 ha (20732.16 feddans) can be improved to be highly suitable (S1) by using succefull cultivation alternatives.

The most profitable agricultural extension can be allocated in the aeolian plain, which covers area of 22229.67 ha (52906.61 feddans) as a promising area for current agricultural land use or for ahead future one. This plain is potentially more suitable for all LUTs and of easy access as mostly is aligning the southern border of the artificial lakes. The status support the interest of recycling and reuse the drained water that is consumed from those lakes facing their borders to be retreated. On other hand planting salinity and marginal fertility tolerant plants such as jojoba shrubs can be managed succefully. In case of temporarily keeping the current traditional cultivation under surface irrigation, cultivation expansion must be restricted to be managed under drip irrigation in the aeolian plain. This water practice in that plain will reduce the problem of current and later on land degradation.

Table 6. Potential land suitability for LUTs after soil improvement

Physiographic unit	Improved current drainage class	Land suitability			Area (hectare)
		Traditional LUTs		Proposed LUT	
		Date palm	Olives	Jojoba	
Aeolian plain (cultivated)	W, MW	S2x	S1	S1	3794.80
*Aeolian plain	E, P and VP	S2x	S1	S1	22229.67
Pediplain (cultivated)	W and MW	S1/ S2c	S1	S1	4916.19
Aeolian dunes	E	S3tx	S2t	S2t	32397.10
	P	N2cp/S3p	S2p	S2p	7715.2
Pediplain	MW	N2cp	N2p /S3	N2p /S2	40431.52
	VP	N2cp	N2p	N2p	9246.53
Mesa	-	N2p	N2p	N2p	4931.19

*** Promising area for agricultural expansion after land improvement. It should be restricted under drip irrigation) if temporarily the current cultivated area still under surface irrigation.**

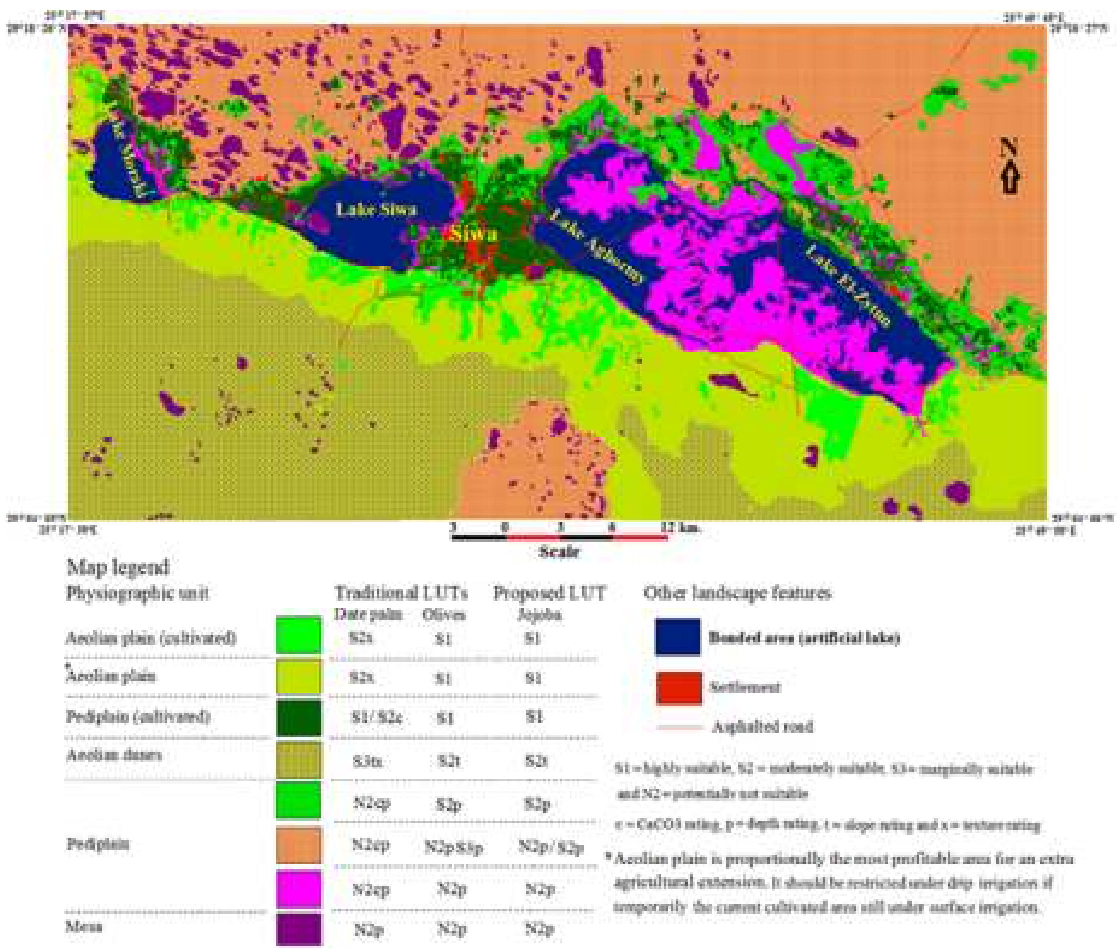

Figure 6. Potential land suitability for different LUTs

Recommendations

- In Siwa, uncontrolled expansion of surface irrigated agriculture accelerated bonding and waterlogging on its unique agrobiodiversity. A comprehensive programme for reducing these impacts is highly required.
- Frequent data for monitoring the land degradation problem should base on measuring land surface features for tracing the directions of water flow and its infiltration in the soils of cultivated areas and their outskirts.
- Ecosystems stability and protecting natural resources of Siwa Oasis should be realized by a better governance of its water and land resources.

- Major improvements that are concerning the limitations and changing the irrigation system require a high capital intensity, which is mostly depend on the government support. For succefull improvement and irrigation system modification, collecting small land tenures within large sized fields is highly required for realizing a commercial scale.
- The most profitable agricultural extension can be allocated in the aeolian plain, which covers area of 22229.67 ha (52906.61 feddans). This plain is potentially more suitable for all LUTs and of easy access as mostly is aligning the southern borders of the artificial lakes. The status support the interest of recycling and reuse the drained water from those lakes facing their borders to be retreated and for planting salinity tolerant plants such as jojoba shrubs.
- In case of temporarily keeping the traditional current cultivation under surface irrigation, cultivation expansion must be conditioned to be managed under drip irrigation in aeolian plain.
- The cultivated area is managed within a limited cultivated land resources in Egypt within an arid zone challenging water sacristy. Formal water practice become a must by saving water use as well as realizing its recycling use.

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رصد تأثير تدهور الأراضي على التنوع الحيوي الزراعي الفريد في واحة سيوة ، مصر

عفيفي عباس عفيفي ، محمود سليمان محمد ، مني كمال مصطفي عبد الرازق وحنان العزب محمد العزب
معهد بحوث الأراضي والمياة والبيئة ، مركز البحوث الزراعية الجيزه ، مصر

تقع منطقة الدراسة داخل محافظة مطروح في شمال غرب مصر. تم تحديد الوحدات الفيزيوجرافية بإستخدام بيانات الأقمار الصناعية TM5 و TM8 في عامي ١٩٨٦ و ٢٠١٨ على التوالي. تشتمل الملامح الفيزيوجرافية على الموائد الصحراوية ، سهل التجوية وهو جزئياً إما منزرع أو متأثر بإرتفاع مستوي الماء الأرضي ، سهل ترسيبات الرياح وهو أيضا جزئيا إما منزرع أو متأثر بإرتفاع مستوي الماء الأرضي ، الكثبان الرملية والمناطق المغمورة بالمياة (بحيرات صناعية). بالإضافة الى ملامح أرضية أخري مثل البنيان السكني والطرق. إزدادت المساحات المغمورة بالمياة من عام ١٩٨٦ إلي ٢٠١٨ بمقدار ١٥٩.٣٨ ، ٨٠.٥٩ ، ٥٢٩٦.٦، ٨.٣٧ ، ٣٤.٣٣ ،هكتار حيث غطت هذه الزيادات سهل التجوية ، سهل التجوية المنزرع ، السهل التحاتي المتأثر بإرتفاع مستوي الماء الأرضي ، سهل ترسيبات الرياح وسهل ترسيبات الرياح المنزرع على التوالي كما إزدادت المساحات المتاثرة بإرتفاع مستوي الماء الأرضي من عام ١٩٨٦ إلي ٢٠١٨ بمقدار 4917.61 ، 1273.21، 3887.37 ، 205.32 و23.50 هكتار فى سهل التجوية ، سهل التجوية المنزرع ، ، سهل ترسيبات الرياح وسهل ترسيبات الرياح المنزرع والكثبان الرملية على التوالي أى أن ٥٥٨٥.٩٧ هكتار وأخرى ١٠٣٠٧.٠ هكتار تحولتا الى مناطق مغمورة بالمياة أو تأثرت بإرتفاع مستوى الماء الارضى على التوالى بمساحة إجمالية لتدهور الأراضى وهى ١٥٨٩٢.٩٧ هكتار. تبين وجود إرتباط بين مستويات صرف التربة ووحدات تصنيف الأراضي على النحو التالي: (أ) الأراضي ذات الصرف الشديد والتى توجد فى سهل ترسيبات الرياح والكثبان الرملية صنفت تحت (*Typic Torripsamments, mixed, (calcareous*(ب) الأراضي ذات الصرف الجيد فى سهل التجوية المنزرع تسود بها الوحدة التصنيفية : *Typic Haplocalcids, fine loamy, mixed* وفى حالة سهل ترسيبات الرياح فإن تربتها صنفت تحت الوحدة التصنيفة *Torripsamments, mixed, Xeric (calcareous)* (ج) أراضي ذات صرف متوسط الجودة فى سهل التجوية وتسود بها الوحدة التصنيفية: Calcic *Haplosalids, coarse loamy, carbonatic*أما الأراضى المنزرعة فى هذا السهل فإن الوحدة التصنيفية للتربة التى تسود فيها هى:*Aquic Haplocalcids, coarse loamy,* mixed أما أراضى سهل الترسيبات الهوائية فإن وحدة التربة التصنيفية هى: *Oxyaquic Torripsamments, mixed (calcareous*) (د) أراضى ذات صرف ردىء وهى توجد فى سهل التجوية وتسودها الوحدة التصنيفية: *Calcic Aquisalids, fine loamy, mixed* أما فى حالة سهل ترسيبات الرياح فإن تربتها قد صنفت تحت الوحدة التصنيفة *Typic Aquisalids, sandy, mixed* (ه) أراضى ذات صرف ردىء جداً وتوجد فى سهل التجوية ويسودها وحدة تصنيف التربة: Gypsic *Aquisalids, fine loamy*, mixed أما الأراضى التى توجد فى سهل الترسيبات الهوائية فقد صنفت الى: *Gypsic Aquisalids, sandy, mixed*تم تقييم أنماط إستخدام الأراضي لكل من نخيل البلح ، الزيتون والجوجوبا بإستخدام نظام الري بالتنقيط وذلك لصلاحيتها تحت الظروف الحالية أو بعد تحسين بعض المحددات فى التربة وقد وجد أن صلاحية الأراضى الحالية تتأثر بمحددات جودة فى التربة مثل كربونات الكالسيوم ، حالة الصرف ملوحه وقلوية التربة ويمكن لهذه الصلاحية أن تكون أكثر ربحية بعد إجراء تحسين حالة الصرف وملوحة وقلوية التربة ومن الأهمية ضم الحيازات الصغيرة عند إجراء تحسين التربة وتعديل نظام الرى لتصبح فى وحدات إقتصادية أفضل وإلى حين أن يتم إحلال الرى السطحى بنظيره بالتنقيط فإن التوسع الزراعى حالياً يجب أن يكون مشروطاً بإستخدام نظام الرى بالتنقيط ويكون أولوية هذا التوسع فى سهل ترسيبات الرياح ذو الصلاحية العالية لزراعة الزيتون والجوجوبا ونظراً لمحازاة هذا السهل للحدود الجنوبية للبحيرات فإنه يكون من السهل إمداده بمياه الصرف التى يمكن تدويرها وإعادة استخدامها بعد إستقطاعها من هذه البحيرات مما يؤدى إلى تراجع مساحاتها وسوف يكون هذا التوسع الزراعى أكثر ربحية فى حالة زراعة الجوجوبا نظراً لقدرتها على تحمل الملوحة والخصوبة الهامشية للتربة فسوف تؤدى هذه الإدارة للمياه والأراضى على هذا السهل إلى تقليل مشكلة تدهور الأراضى الحالية أو المستقبلية ونظراً لموقع مصر فى حزام المنطقة الجافة وفى ظروف محدودية وندرة المياه فإنه من الضرورى تحسين طرق الرى لتوفير كميات من المياه وتدويرها لإعادة إستخدامها