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Original Research Article

Assessmentof land suitability and water requirements for different cropsin Dakhla Oasis, Western Desert, Egypt

Aims: The current work aimed at assessing land suitability and crop water requirements in a desert area in Egypt in order to achieve sustainable agricultural expansion.

Study design: An interpretation of satellite images verified by filed and ground truth was accomplished to fulfill this work.

Place and Duration of Study: The study was carried out on some soils located west of Dakhla Oasis, Western Desert, Egypt, between March 2016 and April 2017.

Methodology: Landsat 8 satellite image and digital elevation model (DEM) covering the studied area were used for identifying the different geomorphic units. Thirty-one soil profiles and eleven water samples were collected and analyzed. MicroLEIS software (Almagra model) was used for computing land suitability forgrowing twelve crops; wheat, maize, watermelon, potato, soya bean, cotton, sunflower, sugar beet, alfalfa, peach, citrus, and olive.

Results: The main geomorphic units are plateau, pediplain, depression and sand sheets. The soils are suitable (high, moderate and marginal) for all the selected crops, except soils of the pediplain unit, as they are not suitable for all the selected crops. Salinity is the predominant limiting factor, followed by lime content, sodium saturation, and soil depth.

Conclusion: If precise agricultural practices are to be performed, the investigated area wouldbe promising for sustainable agricultural expansion.

Keywords: Land suitability, Almagra model, Dakhla Oasis, Western Desert. GIS, Remote sensing

1. INTRODUCTION

Overpopulation, limited arable land, and water scarcity are the main problems facing Egypt[1]. Therefore, increasing the area of cultivated land is vital[2].This is achieved via reclaiming more lands, particularly in the desert which occupy more than 96% of the total area of Egypt[3], especially with the rapid urbanization on the fertile land in the Nile Valley and Delta [4]. Expansion of arable lands provides settlers with new opportunities, increase the national production and support different developmental projects [5, 6].

Major agricultural expansion, industry and civil activities are planned to be in the Western Desert [7, 8], which covers 66.7% of the total area of Egypt and include seven depressions; Siwa, Qattara,

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Fayum, Bahariya, Farafra, Dakhla, and Kharga, where the freshwater exist in the Oases there [9]. The Nubian Sandstone Aquifer (NSSA), the major ground water aquifer in Egypt, is in this desert[10].DakhlaOasis is situated in the heart of the Western Desert. It has high fertile lands and is the main Oasis which supports high population[11]. This is due to the large amount of groundwater presented in this locality, where the thickness of the NSSAranges between 600 and 900 m. Therefore, this area should take a priority in the sustainable development project of southern Egypt [12]. The two main parameters should be under detailed study are soil suitability and wateravailability for crops [13]. Unless there are reliable information concerning land and water resources, agricultural expansionwill not be positive[14].

Land suitability assessmentplaysan important role in planning and managing sustainable land use[15]. It provides useful information and helpsin optimizing agricultural land use[16]. This is due to its impacts on appropriate land use and reasonable urban layout[17]. Remote sensing (RS) provides a cost-effective and quick technique to collect accurate data. Geographic Information System (GIS) manipulate, analyze, and display the data and can also give better results for RS image classification. Thus, a combined use becomes more realistic [18]. They are applied to an area for developing a strategy optimally fitting the local resources and potential productivity [19].One of the most beneficial applications of GIS in planning land recourses is preparing land use maps [20]. Hence, the current work aimed at integrating RS and GIS for mapping agricultural land suitability for some soils located West of DakhlaOasis, Western Desert, Egypt. Crop water requirements for each of the selected crops were also considered to be included in sustainable land used planning.

2. MATERIALS AND METHODS

2.1. The area of study

The studied area covers 555.27 km^2 between longitudes 28°25'13.284" to 28°39'48.753"E and latitude 25°43'49.983" to 25°56'14.844"N(Fig. 1). Brookes [21]and Yousif[22] stated that the area is underlain by a sequence of sedimentary rocks of Cenomanian to Palaeocene eras. Dakhlashales and Quseir formation (variegated shale, mudstone, siltstone and flaggy sandstone) is forming most of the lithological units, while a small part in the area is developed on Duwi formation (mudstones, silicified limestones and phosphorites). According to EMA [23], the area receives very low annual rainfall of 0.5 mm. The mean annual temperature is 23.6 ℃ and the maximum value reaches 40.3 ℃

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during July, while the minimum one decreases to 5.5 ℃ during January. According to Soil Survey Staff [24], the soil temperature regime is Hyperthermic and the soil moisture regime is Tor**ric.**

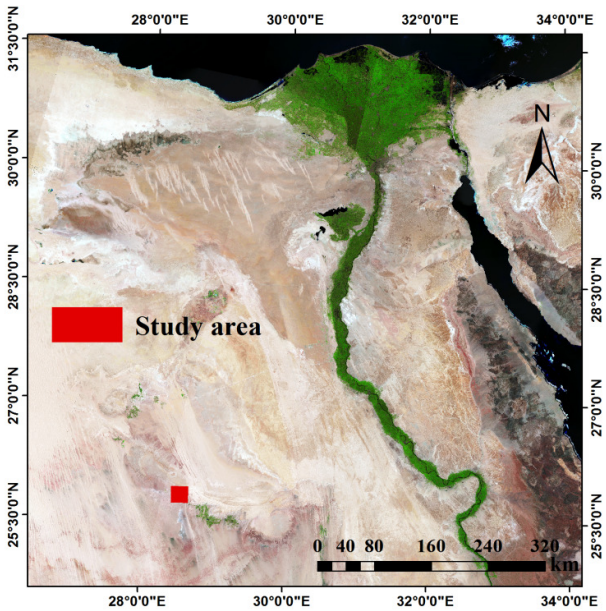

Fig. 1. Location map of the studied area

2.2. Digital image processing

Processing of a Landsat-8operational land imager (OLI) satellite image (path 177, row 42) with a spatial resolution of 30 m dated to 27-03-2016, was executed using ENVI 5.1 Software [25]. Data were calibrated to radiance depending on image type, acquisition date, and time. The image was stretched using linear 2%, smoothly filtered, and their histograms were matched according toLillesand *et al.*[26].The image was atmospherically corrected using FLAASH module. Fusion methodology [27] was applied to produce an image covering the area of study.

2.3. Map creation

A digital elevation model (DEM) of 30 m pixel size resolution, acquired from the Shuttle Radar Topographic Mission (SRTM) images on 27-03-2016, was the source for elevation heights of the study area (Fig. 2). The DEM was presented in 3D mode and was then overlaid by the OLI image to generate a 3D image [28], which was consequently used along with the ground truth data to extract the different landforms of the area. The geomorphic units were described according toZinck and Valenzuela[29]. The produced units were imported into a Geo-database as a base map to generate and display various maps using ArcGIS 10.2.2 software [30].

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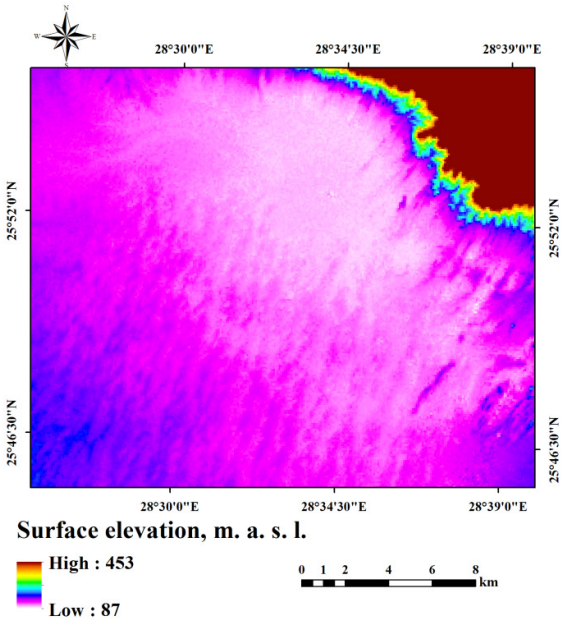

Fig. 2. Digital elevation model (DEM) of the studied area

2.4. Field work and laboratory analysis

Field and ground studies were performed to verify the geomorphologic units and identify the reality of interpretation. Thirty-one soil profiles were georeferenced using GPS and then dug to a depth of 150 cm (Fig. 3). The profiles were described according to the FAO guidelines[31]. Soil samples (151 sample) were collected from the profiles for laboratory analyses using the standard methods outlined by Soil Survey Staff [32]. Keys of soil taxonomy [24]were used to classify soil profiles. Irrigation water samples were collected from eleven drilled water wells and subsequently analyzed. The depth of the drilled wells ranged in depth from 436 m to 1.08 km below the soil surface. Water quality for agriculture was evaluated according to the FAO guidelines for interpretations of water quality for irrigationFAO [33].

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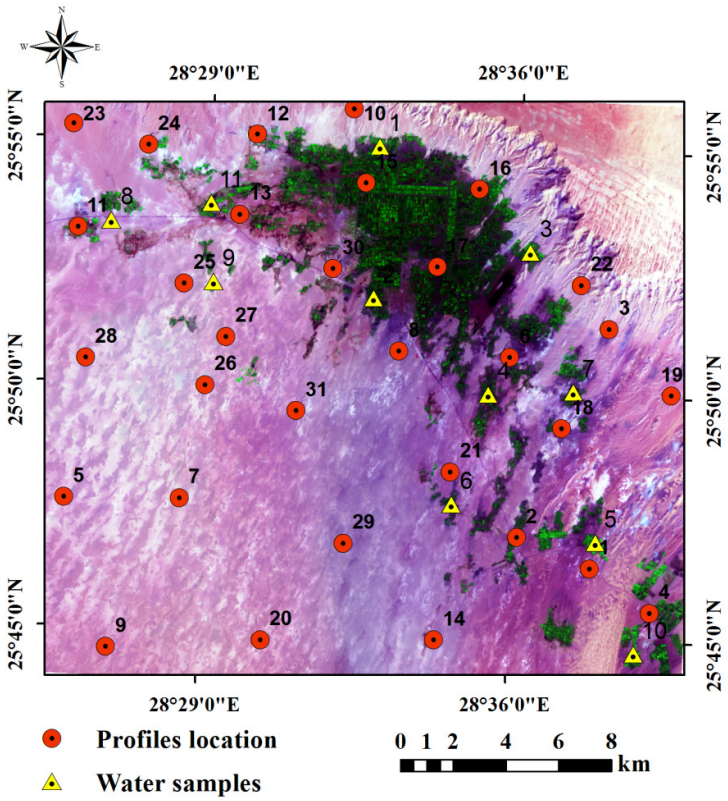

Fig.3. Soil profiles and water samples in the studied area

2.5. Land suitability evaluation

The Microcomputer Land Evaluation Information System (MicroLEIS) package[34]with an Almagra model (Agricultural Soil Suitability) was used for land suitability appraisal. This automatized application of soil suitability methodevaluates agricultural crop suitability based on the FAO framework for land evaluation [35] through matchingland and soil characteristics with growth requirements for selected crops. Land suitability classes are calculated following a semi-quantitative procedure and the results are shown by the computer. Five suitability classes including S1, Optimum; S2, High; S3, Moderate; S4, Marginal, and S5, Not suitable are determined using maximum limitation method [36]. The criteria used for evaluating land suitability are useful depth (cm), stoniness (%), texture, drainage, carbonate content (%), salinity (dS m^{-1}), sodium saturation (%) and soil profile development. Weighted average value for each soil property was calculated by multiplying the parameter value of each horizon by horizon thickness and divided by the total profile depth. The weighted values were inputted into Almagra model in order to run suitability evaluation for twelve crops; wheat, maize, watermelon, potato, soya bean, cotton, sunflower, sugar beet, alfalfa, peach, citrus, and olive.

2.6. Crop water requirements

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Crop water requirements are commonly estimated with the FAO-56 methodology. This procedure based upon a two-step: first a reference evapotranspiration (ETo) is calculated from COPWAT 8.0 software using weather variables with the Penman-Monteith equation, then the ETo is multiplied by a tabulated crop-specific coefficient (Kc) adapted from Allen *et al.* [37]to determine the water requirement (ETc) of a given crop under standard conditions[38].

3. RESULTS AND DISCUSSION

3.1.Geomorphology of the studied area

The landforms and physiographic units are presented in Fig.4 and Table 1.The main landscapesin the area are plateau, pediplain, depression, and Aeolian plain. The plateau covers 46.45 km^2 in the northeastern zone and represents 8.37% of the total area.It includes the landforms of summit (33.13 km^2) and escarpment (13.32 km^2). The pediplain occupies the smallest part, which represents 2.87 % of the total area, covering 15.91 km^2. The depression covers the greatest part, 60.80% of the total area, and occupies 337.62 km^{2}in the middle part of the area. The included landforms within this landscape are depression edge (130.21 km^2) and depression floor (207.41 km^2). The Aeolian plain covers 155.29 km^{2}and represents27.97% of the total area. The landforms in this landscape are sand sheets (low and moderate), covering 119.28 and 36.01 km^2, respectively.

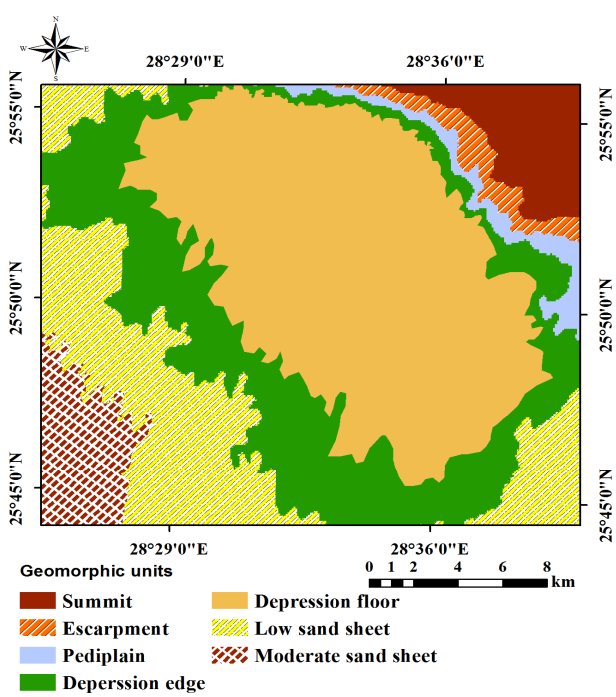

Fig. 4. Landforms of the studied area

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Table 1. Physiographic legend and soils of the studied area

Landscape	Relief	Lithology/origin	Landform	Area, km^2	Area, %	Main soil	Kind of mapping unit
Plateau	Almost flat	Limestone	Summit	33.13	5.97	Rocky area	----
	Rolling		Escarpment	13.32	2.40		
Pediplain	Flat to almost flat	Limestone, siltstone, sandstone	Pediplain	15.91	2.87	TypicTorriorthents	Consociation
Depression	Gently undulating	Shale, clay stone, limestone, siltstone, sandstone	Depression edge	130.21	23.45	TypicTorriorthents TypicHaplocalcids TypicHaplosalids	Complex
	Almost flat		Depression floor	207.41	37.35	TypicTorriorthents VerticTorriorthents	Association
Aeolian plain	Gently undulating	Sandstone, limestone	Low sand sheet	119.28	21.48	TypicTorripsamments	Consociation
			Moderate sand sheet	36.01	6.49		

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3.2. Soils of the study area

3.2.1. Soils of the pediplain

The soils are gently sloping and moderately deep to deep since values of slope ranged from 2.72 to 2.76 and the value for soil depth ranged from 70 to 110 cm (Table 2). Gravelly and very gravelly sandy loam ~~areis the two textural classes~~ observed within this landform. The soils are slightly to moderately alkaline and slightly to strongly saline since pH ranged from 7.61 to 7.88, while EC ranged from 7.22 to 23.90 dS m^{-1}. Soil organic matter varied from 0.92 to 1.25 g kg^{-1}. Calcium carbonate and gypsum varied from 154.10 to 548.20 g kg^{-1} for the former and from 52.32 to 61.46 g kg^{-1} for the latter. CEC ranged from 7.80 to 11.60cmolc kg^{-1} soil. ~~The low organic matter and clay contents are the main reason for such low values.~~ ESP varied from 2.21 to 8.92, indicating none-sodic soils. The main soil subgroupis TypicTorriorthents.

3.2.1. Soils of the Depression

The soils are flat to very gently sloping and moderately deep to very deep. Slope ~~values~~ ranged from 0.31 to 1.89% and ~~soil depth ranged 95 to 150 cm.~~ Soil texture ~~ranges from~~ sandy loam to clay. Soil pH varied from 7.18 to 7.82, indicating neutral to moderate alkalinity. Soil salinity varied from slightly saline to strongly saline with EC ~~ranging between~~ 5.11 and 40.52 dS m^{-1}.As a result of the absence of natural vegetation and aridity, soil organic matter was low ~~and ranged from~~ 0.59 to 10.75 g kg^{-1}. Calcium carbonate and gypsum contents ~~ranged~~ from 56.10 to 1.12 g kg^{-1} and from 8.15 to 81.22 g kg^{-1}, respectively. Cation exchange capacity (CEC) varied from 12.30 to 54.10 cmolc kg^{-1} soil, while exchangeable sodium percentage (ESP) ~~varied~~ from 2.51 to 32.33.The main soil subgroups are TypicTorriorthents, VerticTorriorthents, TypicHaplosalids and TypicHaplocalcids. .

3.2.3. Soil of the sand sheet

The slope ranged from 1.21 to 8.56%, which means that the soils are very gently sloping to sloping. The soils are moderately deep to very deep since soil depth ranged from 90 to 190 cm. The soils have sand to slightly gravelly loam sand texture. Values of pH and EC ranged from 7.46 to 8.03 and from 5.67 to 23.53 dS m^{-1}, respectively. Thus, the soils are slightlyto moderatelyalkaline and slightly to strongly saline~~. Soil organic matter ranged from 0.74 to 4.92 g kg^{-1}~~. Calcium carbonate and gypsum ranged from106.10 to 604.20g kg^{-1} for the former and from 21.33 to 36.52 g kg^{-1} for the latter. CEC ~~ranged~~ from 7.60 to 29.20 cmolc kg^{-1} soil and ESP ~~ranged from~~ 4.10 to 30.41.The main soil subgroup is TypicTorripsamments.

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Table 2. Main soil properties of the studied area

Soil properties	Pediplain	Depression	Sand sheet
Slope, %	2.72 - 2.76	0.31 - 1.89	1.21 - 8.56
Gravel, %	15.11 – 44.89	0.13 – 3.96	0.56 – 11.45
Soil depth, cm	70 - 110	95 - 150	90 - 130
Soil texture	GSL - VGSL	SL - C	S - SGLS
pH	7.61 - 7.88	7.18 - 7.82	7.46 - 8.03
EC, dS m^{-1}	7.22 - 23.90	5.11 - 40.52	5.67 - 23.53
OM, g kg^{-1}	0.92 - 1.25	0.59 - 10.75	0.74 - 4.92
$CaCO_3$, g kg^{-1}	154.10 - 548.20	56.10 - 449.29	106.10 - 604.20
Gypsum, g kg^{-1}	52.32 - 61.46	8.15 - 81.22	21.33 - 36.52
CEC, cmolc kg^{-1}	7.80 - 11.60	12.30 - 54.10	7.60 - 29.20
ESP	2.21 - 8.92	2.51 - 32.33	4.10 - 30.41

VG, very gravelly; G, gravelly; SG; slightly gravelly; SL, sandy laom; C, clay; S, sand; LS, loamy sand

3.3. Water quality for irrigation

Eleven water wells were samples to test the water quality, measuring the pH, EC, TDS, TH, and calculating the SAR and RSC.Chemical composition of irrigation water is shown in Table 3. Results illustrate that that pH values ranged from 6.85 to 7.82, indicating a normal range for irrigation (6.5 – 8.4).Salinity shows low values in all wells with EC ranging from 0.21 to 0.31 dS m^{-1}. Values of SAR ~~ranged~~ from 0.58 to 1.12, ~~while RSC showed negative values~~. The results indicate that waterquality is ~~high, and consequently water is suitable~~ for irrigating all the proposed crops. Such high water quality enables crop cultivation under salinity and ~~socicity~~stress.Water quantity and quality play a vital role in land-use planning, especially under irrigated agriculture [39].

3.4. Crop water requirements

The crop water requirements for the selected crops are presented in Table 4. Values of the ETo from January to December were 3.1, 3.9, 5.3, 6.8, 8.4, 8.7, 8.8, 8.3, 7.3, 5.7, 3.8 and 2.9 mm day^{-1}. The calculated ETcfor the selected crops were as follows: maize = 816.33 mm, sunflower = 795.98 mm, soya bean = 1003.83 mm, wheat = 550.78 mm, sugar beat = 865.13 mm, cotton = 1150.83 mm, watermelon = 797.87 mm, alfalfa = 2113.47 mm, potato = 397.37 mm, peach = 1577.86, citrus = 1503.92 mm and olive = 1163.96 mm.

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Table 3. Chemical composition of irrigation water samples

	pH	EC, dS m^{-1}	TDS, mg L^{-1}	SAR	RSC
1	7.61	0.21	122.00	0.58	-0.66
2	7.82	0.30	177.00	0.97	-0.74
3	6.95	0.29	179.00	0.95	-0.81
4	6.91	0.26	153.00	0.86	-0.62
5	6.93	0.25	147.00	1.12	-0.58
6	6.85	0.24	142.00	0.75	-0.64
7	7.73	0.21	124.00	0.66	-0.51
8	7.61	0.29	175.00	1.12	-0.76
9	7.31	0.25	150.00	0.95	-0.62
10	7.52	0.26	155.00	0.96	-0.95
11	7.11	0.31	188.00	1.03	-0.75

EC, electrical conductivity; TDS, total dissolved solids; SAR, sodium adsorption ratio; RSC, residual sodium carbonate

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Table 4.Crop water requirements (mm season^{-1}) for the proposed crops in the studied area

Month	ETo, mm day^{-1}	Maize		Sunflower		Soya bean		Wheat	
		Kc	ETc, mm month^{-1}	Kc	ETc, mm month^{-1}	Kc	ETc, mm month^{-1}	Kc	ETc, mm month^{-1}
Jan	3.10							0.93	89.37
Feb	3.90							1.15	125.58
March	5.30							1.15	188.95
April	6.80					0.50	102.00	0.72	146.88
May	8.40	0.30	78.12	0.35	91.14	0.86	223.94		
June	8.70	0.89	232.29	0.91	237.51	1.00	261.00		
July	8.80	1.10	300.08	1.10	300.08	1.00	272.80		
August	8.30	0.80	205.84	0.65	167.25	0.56	144.09		
September	7.30								
October	5.70								
November	3.80								
December	2.90								
Total ETc, mm season^{-1}			**816.33**		**795.98**		**1003.83**		**550.78**
Month	**ETo, mm day^{-1}**	**Sugar beat**		**Cotton**		**Watermelon**		**Alfalfa**	
		Kc	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**
Jan	3.10	1.05	100.91					0.95	91.30
Feb	3.90	1.20	131.04					0.95	103.74
March	5.30	1.20	197.16	0.35	57.51			0.95	156.09
April	6.80	1.18	240.72	0.40	81.60	0.55	112.20	0.95	193.80
May	8.40	0.75	195.30	0.83	216.13	0.78	203.11	0.95	247.38
June	8.70			1.10	287.10	0.95	247.95	0.95	247.95
July	8.80			1.10	300.08	0.86	234.61	0.95	259.16
August	8.30			0.81	208.41			0.95	244.44
September	7.30							0.95	208.05
October	5.70							0.95	167.87
November	3.80							0.95	108.30
December	2.90							0.95	85.41
Total ETc, mm season^{-1}			**865.13**		**1150.83**		**797.87**		**2113.47**
Month	**ETo, mm day^{-1}**	**Potato**		**Peach**		**Citrus**		**Olive**	
		Kc	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**	**Kc**	**ETc, mm month^{-1}**
Jan	3.10	0.97	93.22			0.75	72.08	0.50	48.05
Feb	3.90					0.75	81.90	0.50	54.60
March	5.30			0.55	90.37	0.73	119.94	0.65	106.80
April	6.80			0.68	138.72	0.70	142.80	0.61	124.44
May	8.40			0.83	216.13	0.67	174.47	0.55	143.22
June	8.70			0.90	234.90	0.65	169.65	0.48	125.28
July	8.80			0.90	245.52	0.65	177.32	0.45	122.76
August	8.30			0.90	231.57	0.65	167.25	0.45	115.79
September	7.30			0.90	197.10	0.65	142.35	0.49	107.31
October	5.70	0.60	106.02	0.82	144.89	0.66	116.62	0.56	98.95
November	3.80	0.91	103.74	0.69	78.66	0.68	77.52	0.63	71.82
December	2.90	1.05	94.40			0.69	62.03	0.50	44.95
Total ETc, mm season^{-1}			**397.37**		**1577.86**		**1503.92**		**1163.96**

ETo, referenced crop evapotranspiration; ETc, water requirements

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3.5. Land suitability for selected crops

The agricultural suitability performed by applying MicroLEIS-Almagra model for different mapping units is presented in Fig. 5 and Table 5. Calculations were done using modal profile representing the dominant ~~main~~ soil in each mapping unit.Soils of depression and sand sheets are high suitablesuitable (S2), moderately suitable (S3) and marginally suitable (S4) for all selected crops, except watermelon, peach, citrus, and olive, as the soils are moderately suitable (S3), marginally suitable (S4) and not suitable (S5), respectively. On the other hand, soils of pediplain have severe limitations, and thus they are not suitable (S5) for all the selected crops. The most recommended crop in the area is ~~sugar peat~~, as 66.35% of the soils are suitable (S2).

The limiting factors ~~in the study~~ area are salinity, followed by lime content, sodium saturation, and soil depth. Salinity and alkalinity~~, modifiable limitations,~~ are difficult to ~~be improved in the area of study. This is due to the predominant of salt enriched parent materials underlain the area which is composed mainlyof shale and limestone~~[40, 41]. Also, high evaporation rate results in salt accumulation at the soil surface[42]. Finally, the impermeable layers under the shallow soil profiles prevent water percolation and lead to high water table levels[43].Soil depth and lime content are permanent limiting factors which could not be improved. Soil depth is very apparent in the pediplain unit, in particular for fruit crops. The importance of soil depth goes beyond the ease of root penetration and development [44]. Lime affects soil water relations and the availability of plant nutrients[45].

Sustainable development in the study area requires precise agricultural practices. Growing salt and drought-tolerant cultivars is the first step to cope with salinity and alkalinity [46]. Rationalized irrigation using modern systems (drip and subsurface drip irrigation), night irrigation, shorter irrigation intervals and proper water requirements have been also recommended for reclaiming impermeable calcareous saline-sodic soils [47-50]. ~~Inhibitingsalt accumulation at surface soil iseffective in salinity control.~~ It can be supported by deep plowing to cut off capillarity from groundwater, preventing the rise of salts to top soil [51], and soil mulching using synthetic and natural materials [52]. As the soils contain high amounts of lime, applying sulfuric acid with irrigation water can reduce sodicity[53]. Sulfuric acid reacts with carbonates, providing a soluble source of Ca^{2+} which replacesNa^{+} on the exchangeable sites [54]. Moreover, enhancing fertility status via balanced fertilization [55], organic manuring [56], foliar application of micronutrients to avoid their fixation in soil [57],and inoculation with plant growth promoting microbes[58] proved success in increasing crop yield in such unfavorable conditions.

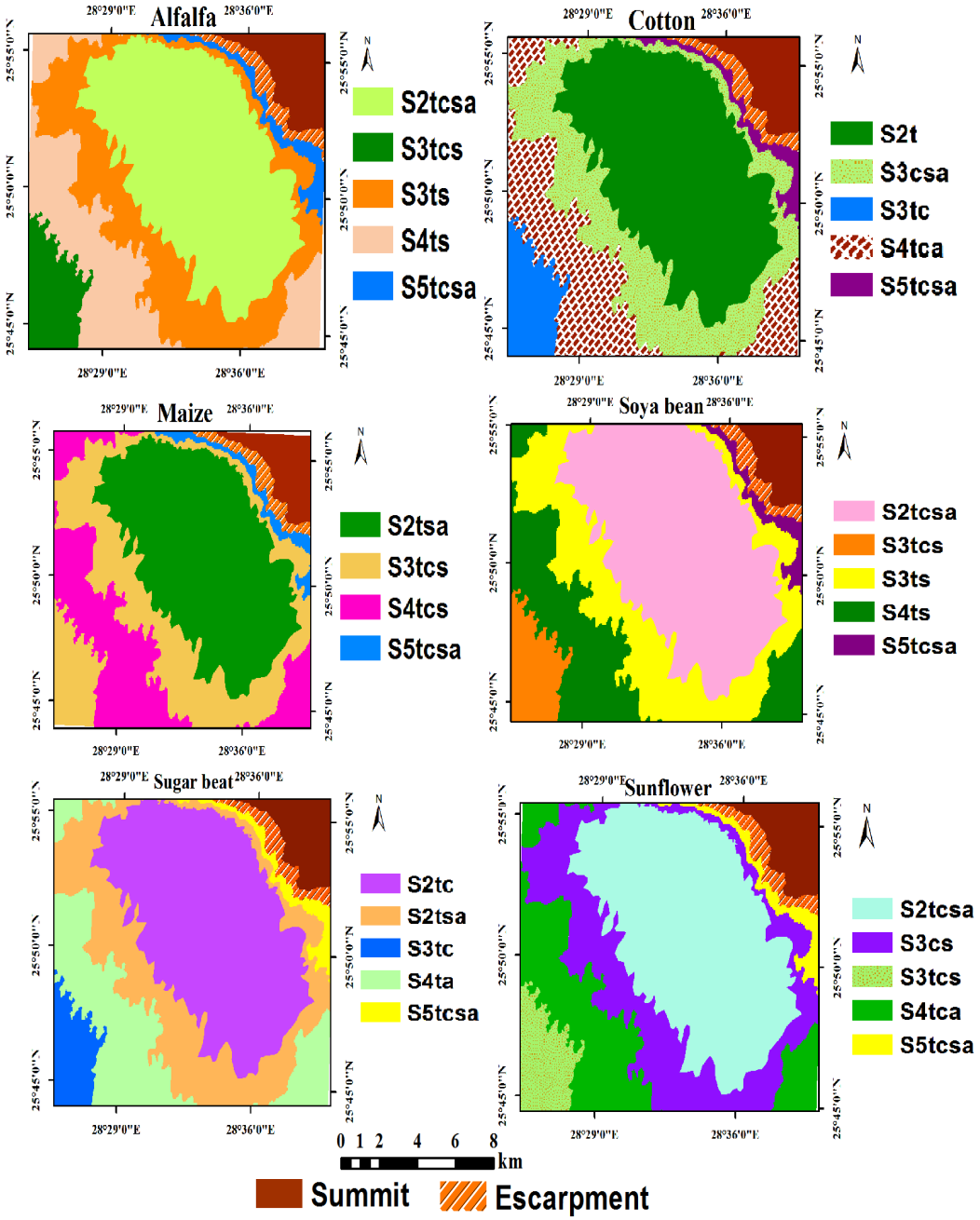
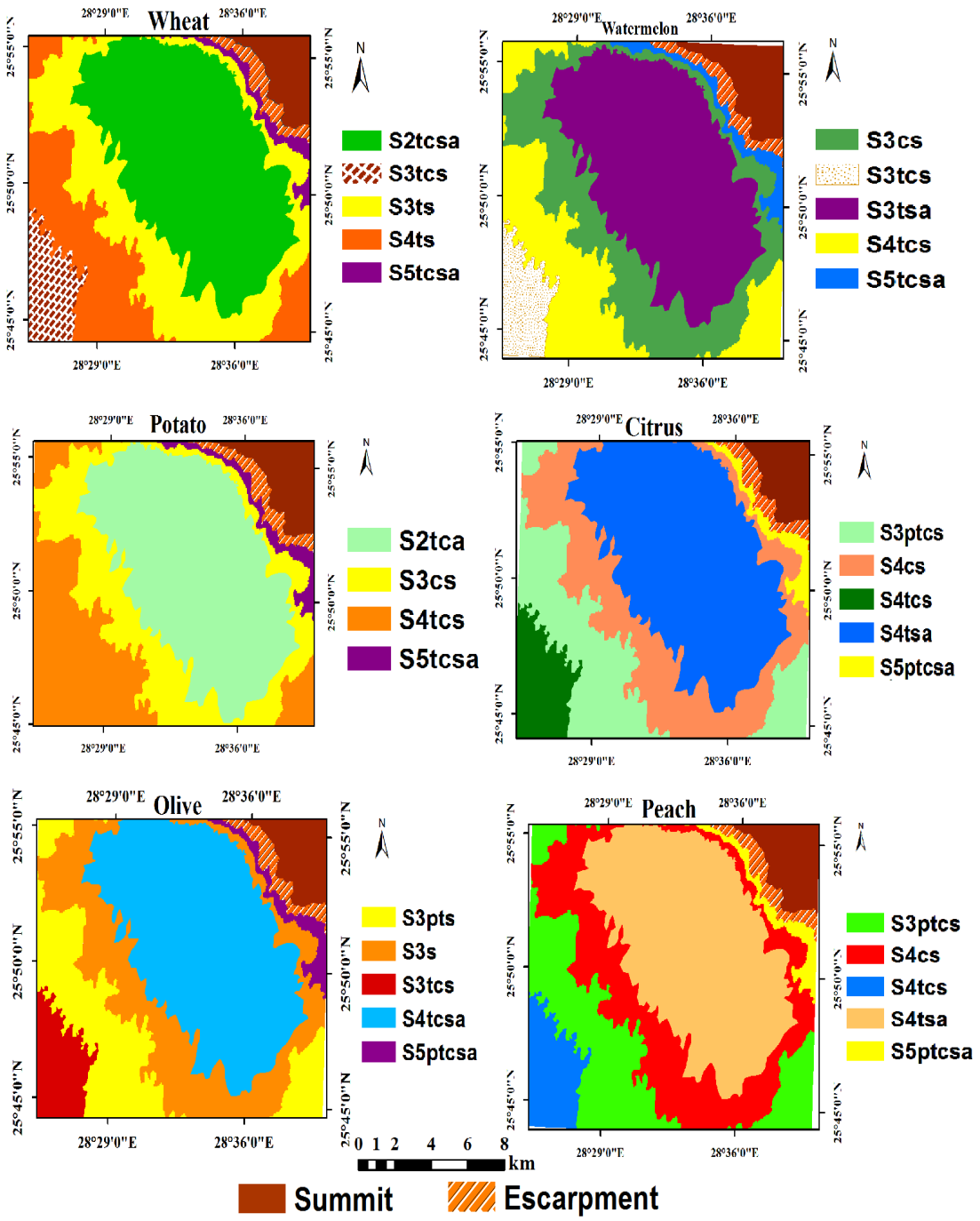


Fig. 5. Land suitability for the selected crops in the study area


Wheat
S2tcsa
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Watermelon
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Citrus
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Olive
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25°45'0"N
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0 1 2 4 6 8
km
Summit
Escarpment

Fig. 5.Cont.

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Table 5.Relative extent of land suitability in the studied area

Crop	S2		S3		S4		S5	
	Area, km^2	Area, %	Area, km^2	Area, %	Area, km^2	Area, %	Area, km^2	Area, %
Wheat	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Maize	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Watermelon	--	--	373.63	73.43	119.28	23.44	15.91	3.13
Potato	207.41	40.76	130.21	25.59	155.29	30.52	15.91	3.13
Soya bean	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Cotton	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Sunflower	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Sugar beat	337.62	66.35	36.01	7.08	119.28	23.44	15.91	3.13
Alfalfa	207.41	40.76	166.22	32.67	119.28	23.44	15.91	3.13
Peach	--	--	119.28	23.44	373.63	73.43	15.91	3.13
Citrus	--	--	119.28	23.44	373.63	73.43	15.91	3.13
Olive	--	--	285.50	56.11	207.41	40.76	15.91	3.13

S2, highly suitable; S3, moderately suitable; S4, marginally suitable; S5, not-suitable

4. CONCLUSION

Assessment of land suitability for different crops helps in planning sustainable agriculture programs. An approach integrating remote sensing, GIS and the MicroLIESsoftware (Almagra model) was undertaken in this study to assess land performance of 555.27 km^2 (132154.26feddans = 55527 hectares) west of Dakhla oasis. About 97% of the studied soils are suitable for all the selected crops, while the remaining area (about 3%) is notsuitable. The most predominant limiting factors are salinity, lime content, sodicity and soil depth. Sustainable agriculture in the studied area requiresgood agricultural practices, and constructing modern irrigation systems to cope with limitations. The area is characterized by high water quality, giving it a priority in agricultural expansion projects.

REFERENCES

1. Zidan, M.S. and M.A. Dawoud, Agriculture use of marginal water in Egypt: Opportunities and challenges, in Developments in Soil Salinity Assessment and Reclamation. 2013, Springer, Nederland p. 661-679.
2. kamel, M. and E.S.M. Abu El Ella, Integration of Remote Sensing & GIS to Manage the Sustainable Development in the Nile Valley Desert Fringes of Assiut-Sohag Governorates, Upper Egypt. J. Indian Soc. Remot, 2016. 44(5): p. 759-774.10.1007/s12524-015-0529-2
3. El-Ramady, H.R., S.M. El-Marsafawy, and L.N. Lewis, Sustainable agriculture and climate changes in Egypt, in Sustainable agriculture reviews. 2013, Springer. p. 41-95.

UNDER PEER REVIEW

4. Shalaby, A. and F.S. Moghanm, Assessment of urban sprawl on agricultural soil of northern Nile Delta of Egypt using RS and GIS. Chin. geogr. sci., 2015. 25(3): p. 274

5. Adriansen, H.K., Land reclamation in Egypt: A study of life in the new lands. Geoforum, 2009. 40(4): p. 664-674.10.1016/j.geoforum.2009.05.006

6. Kamel, M. and E.M. Abu El Ella, Integration of Remote Sensing & GIS to manage the sustainable development in the Nile valley desert fringes of Assiut-Sohag Governorates, Upper Egypt. Journal of the Indian Society of Remote Sensing, 2016. 44(5): p. 759-774.10.1007/s12524-015-0529-2

7. El Kashouty, M., A.A. Aziz, M. Soliman, and H. Mesbah, Hydrogeophysical investigation of groundwater potential in the El Bawiti, Northern Bahariya Oasis, Western Desert, Egypt. Arab. J. Geosci., 2012. 5(5): p. 953-970.10.1007/s12517-010-0253-8

8. Abdel Kawy, W.A. and K.M. Darwish, Assessment of optimum land use and water requirements for agricultural purpose in some soils South Paris Oasis, Western Desert, Egypt. Arab. J. Geosci., 2014. 7(10): p. 4043-4058.10.1007/s12517-013-1054-7

9. Khan, S.D., M.S. Fathy, and M. Abdelazeem, Remote sensing and geophysical investigations of Moghra Lake in the Qattara Depression, Western Desert, Egypt. Geomorphology, 2014. 207: p. 10-22.http://dx.doi.org/10.1016/j.geomorph.2013.10.023

10. Elsheikh, A.E., Mitigation of groundwater level deterioration of the Nubian Sandstone aquifer in Farafra Oasis, Western Desert, Egypt. Environ. Earth Sci., 2015. 74(3): p. 2351-2367.10.1007/s12665-015-4236-7

11. Kato, H., R. Kimura, S.F. Elbeih, E. Iwasaki, and E.A. Zaghloul, Land use change and crop rotation analysis of a government well district in Rashda village – Dakhla Oasis, Egypt based on satellite data. Egypt. J. Rem. Sens. Space Sci., 2012. 15(2): p. 185-195.http://dx.doi.org/10.1016/j.ejrs.2012.09.003

12. Senosy, M.M., M.M. Youssef, and M. Abdel Zaher, Sedimentary cover in the South Western Desert of Egypt as deduced from Bouguer gravity and drill-hole data. Journal of African Earth Sciences, 2013. 82: p. 1-14.http://dx.doi.org/10.1016/j.jafrearsci.2013.02.001

13. Kawy, W.A. and K.M. Darwish, Assessment of optimum land use and water requirements for agricultural purpose in some soils South Paris Oasis, Western Desert, Egypt. Arab J. Geosci., 2014. 7(10): p. 4043-4058

UNDER PEER REVIEW

14. Abdel Kawy, W.A.M. and I.H. Abou El-Magd, Use of satellite data and GIS for assessing the agricultural potentiality of the soils South Farafra Oasis, Western Desert, Egypt. Arab. J. Geosci., 2013. 6(7): p. 2299-2311.10.1007/s12517-012-0518-5

15. Hamzeh, S., et al., Feature Selection as a Time and Cost-Saving Approach for Land Suitability Classification (Case Study of Shavur Plain, Iran). Agriculture-Basel, 2016. 6(4).10.3390/agriculture6040052

16. Albaji, M. and A. Alboshokeh, Assessing agricultural land suitability in the Fakkeh region, Iran. Outlook Agric., 2017. 46(1): p. 57-65.10.1177/0030727017690659

17. Jiao, S., X.L. Zhang, and Y. Xu, A review of Chinese land suitability assessment from the rainfall-waterlogging perspective: Evidence from the Su Yu Yuan area. J. Clean. Prod., 2017. 144: p. 100-106.10.1016/j.jclepro.2016.12.162

18. van Dijk, A. and M.G. Bos, GIS and Remote Sensing Techniques in Land-and Water-management. 2013: Springer Science & Business Media.

19. Singh, R.B. and D. Kumar, Remote sensing and GIS for land use/cover mapping and integrated land management: case from the middle Ganga plain. Frontiers of Earth Science, 2012. 6(2): p. 167-176.10.1007/s11707-012-0319-x

20. Maddahi, Z., A. Jalalian, M.M.K. Zarkesh, and N. Honarjo, Land Suitability Analysis for Rice Cultivation Using a GIS-based Fuzzy Multi-criteria Decision Making Approach: Central Part of Amol District, Iran. Soil Water Res., 2017. 12(1): p. 29-38.10.17221/1/2016-swr

21. Brookes, I.A., Spatially variable sedimentary responses to orbitally driven pluvial climate during Marine Oxygen Isotope Stage 5.1, Dakhla Oasis region, Egypt. Quaternary Res., 2010. 74(2): p. 252-264.10.1016/j.yqres.2010.05.001

22. Yousif, I.A., Land evaluation and sustainable development of some areas of Dakhla Oasis, Egypt, in Ph.D Thesis 2014: Faculty of Agriculture, Cairo University, Egypt.

23. EMA, The normals for Dakhla station, (1960 – 2010). Egyptian Meteorological Authority (EMA). Ministry of Civil Aviation, Cairo, Egypt. 2011

24. Soil Survey Staff, Keys to soil taxonomy. 12 th Ed. 2014, Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service.

25. ITT, ITT corporation ENVI 5.1 Software, 1133 Westchester Avenue, White Plains, New York, USA. 2014.

UNDER PEER REVIEW

26. Lillesand, T., R.W. Kiefer, and J. Chipman, Remote sensing and image interpretation. 2014: John Wiley & Sons, USA.

27. Ranchin, T., B. Aiazzi, L. Alparone, S. Baronti, and L. Wald, Image fusion—the ARSIS concept and some successful implementation schemes. ISPRS Journal of Photogrammetry and Remote Sensing, 2003. 58(1): p. 4-18

28. Dobos, E., B. Norman, and B. Worstell, The use of DEM and satellite data for regional scale soil databases. Agrokémia és Talajtan, 2002. 51(1-2): p. 263-272

29. Zinck, J.A. and C.R. Valenzuela, Soil geographic database: structure and application examples. ITC J., 1990(No. 3): p. 270-294

30. ESRI, Arc Map version 10.2. User Manual. ESRI, 380 New York Street, Redlands, California, USA. 2014.

31. FAO, Guidelines for soil description. Fourth edition. Fourth ed. 2006, FAO, Rome.

32. Soil Survey Staff, Soil survey field and laboratory methods manual. Soil Survey Investigations Report No. 51, Version 1.0. 2009: U.S. Department of Agriculture, Natural Resources Conservation Service.

33. FAO, Water quality for agriculture: FAO Irrigation and Drainage Paper 29. Revision. 1. pp. 1-130. 1994

34. Rosa, D., Agro-ecological land evaluation for sustainable rural development (in Spanish). Mundi-Prensa Press, Madrid., Spain, 2008

35. FAO, A framework for land evaluation. . Soils Bulletin 32. FAO, Rome., 1976

36. Sys, C., E. Van Ranst, and J. and Debaveye, Land evaluation, part II. Methods in land evaluation. General administration for development cooperation, Brussels, pp: 247. 1991

37. Allen, R.G., L.S. Pereira, D. Raes, and M. Smith, Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome, 1998. 300(9): p. D05109

38. Lhomme, J.P., N. Boudhina, M.M. Masmoudi, and A. Chehbouni, Estimation of crop water requirements: extending the one-step approach to dual crop coefficients. Hydrol. Earth Syst. Sc., 2015. 19(7): p. 3287-3299.10.5194/hess-19-3287-2015

UNDER PEER REVIEW

39. Kawy, W.A.A. and I.H.A. El-Magd, Assessing crop water requirements on the bases of land suitability of the soils South El Farafra Oasis, Western Desert, Egypt. Arab J. Geosci., 2013. 6(7): p. 2313-2328.10.1007/s12517-012-0519-4

40. Adelsberger, K.A. and J.R. Smith, Paleolandscape and paleoenvironmental interpretation of spring-deposited sediments in Dakhleh Oasis, Western Desert of Egypt. CATENA, 2010. 83(1): p. 7-22.10.1016/j.catena.2010.06.009

41. El-Desoky, H., A. Khalil, S. Farouk, and W. Fahmy, Dakhla–Kharga iron-rich paleosols, Western Desert, Egypt: geology, geochemistry, and mineralization. Arab J. Geosci., 2017. 10(4): p. 74.10.1007/s12517-017-2853-z

42. Hereher, M.E. and H. Ismael, The application of remote sensing data to diagnose soil degradation in the Dakhla depression–Western Desert, Egypt. Geocarto Int., 2016. 31(5): p. 527-543

43. Aldabaa, A., et al., Land suitability classification of a desert area in Egypt for some crops using microleis program. Am Eurasian J. Agric. Environ. Sci., 2010. 8(1): p. 80-94

44. De la Rosa, D., F. Mayol, E. Diaz-Pereira, M. Fernandez, and D. De la Rosa, A land evaluation decision support system (MicroLEIS DSS) for agricultural soil protection: With special reference to the Mediterranean region. Environ. Model. Softw., 2004. 19(10): p. 929-942

45. Aboukila, E.F., I.N. Nassar, M. Rashad, M. Hafez, and J.B. Norton, Reclamation of calcareous soil and improvement of squash growth using brewers' spent grain and compost. Journal of the Saudi Society of Agricultural Sciences (in Press), 2016.http://doi.org/10.1016/j.jssas.2016.09.005

46. Dordas, C., et al., Evaluation of Barley Cultivars for their Tolerance to Salinity under Field Conditions for Utilization to Saline Soils. Procedia Environ. Sci., 2015. 29: p. 270-271.http://doi.org/10.1016/j.proenv.2015.07.205

47. Salvador, R. and R. Aragues, State of the art of subsurface drip irrigation: Design, management, maintenance and soil salinity control. Itea-Inf Tec. Econ. Ag., 2013. 109(4): p. 395-407

48. Zhang, T., X. Zhan, Y. Kang, S. Wan, and H. Feng, Improvements of soil salt characteristics and nutrient status in an impermeable saline–sodic soil reclaimed with an improved drip

UNDER PEER REVIEW

irrigation while ridge planting Lycium barbarum L. J. Soils Sediments, 2017. 17(4): p. 1126-1139.10.1007/s11368-016-1600-5

49. Ali, M.H., Management of Salt-Affected Soils, in Practices of Irrigation & On-farm Water Management: Volume 2. 2011, Springer New York: New York, NY. p. 271-325.

50. Al-Omran, A.M., A.S. Sheta, A.M. Falatah, and A.R. Al-Harbi, Effect of drip irrigation on squash (Cucurbita pepo) yield and water-use efficiency in sandy calcareous soils amended with clay deposits. Agric. Water Manag., 2005. 73(1): p. 43-55.http://doi.org/10.1016/j.agwat.2004.09.019

51. Araya, A., et al., Deep Tillage Plough down to 600 mm for Improvement of Salt-affected Soils: Part 1: Configuration of Plough for Production of Large Soil Clods in Subsoil. Eng. Agric. Environ. Food, 2012. 5(1): p. 7-14.http://doi.org/10.1016/S1881-8366(12)80002-4

52. Aragues, R., E.T. Medina, and I. Claveria, Effectiveness of inorganic and organic mulching for soil salinity and sodicity control in a grapevine orchard drip-irrigated with moderately saline waters. Span. J. Agric. Res., 2014. 12(2): p. 501-508.10.5424/sjar/2014122-5466

53. Yazdanpanah, N. and M. Mahmoodabadi, Reclamation of calcareous saline–sodic soil using different amendments: Time changes of soluble cations in leachate. Arab J. Geosci., 2013. 6(7): p. 2519-2528.10.1007/s12517-011-0505-2

54. Mahmoodabadi, M., N. Yazdanpanah, L.R. Sinobas, E. Pazira, and A. Neshat, Reclamation of calcareous saline sodic soil with different amendments (I): Redistribution of soluble cations within the soil profile. Agric. Water Manag., 2013. 120: p. 30-38.http://doi.org/10.1016/j.agwat.2012.08.018

55. Naseem, B. and I. Arif, A thermo-acoustical study to explore interactions between soil salts and fertilizer in view to control the soil salinity. J. Mol. Liq., 2017. 225: p. 64-86.10.1016/j.molliq.2016.10.143

56. Ranjbar, F. and M. Jalali, The effect of chemical and organic amendments on sodium exchange equilibria in a calcareous sodic soil. Environ. Monit. Assess., 2015. 187(11): p. 683.10.1007/s10661-015-4894-7

57. Fahad, S., K.M. Ahmad, M.A. Anjum, and S. Hussain, The Effect of Micronutrients (B, Zn and Fe) Foliar Application on the Growth, Flowering and Corm Production of Gladiolus (Gladiolus grandiflorus L.) in Calcareous Soils. J. Agric. Sci. Tec., 2014. 16: p. 1671-1682

UNDER PEER REVIEW

58. Arora, S. and M. Vanza, Microbial Approach for Bioremediation of Saline and Sodic Soils, in Bioremediation of Salt Affected Soils: An Indian Perspective, S. Arora, A.K. Singh, and Y.P. Singh, Editors. 2017, Springer International Publishing: Cham. p. 87-100.