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Land evaluation of old and recent cultivated reclaimed desert sandy soils in Egypt.

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The main objective of this research article is to assess the impact of cultivation period on the land capability for agriculture and suitability for crops in the reclaimed desert sandy soils of Modriat El-Tahrir, El-Beheira Governorate, Egypt. The studied area was reclaimed and cultivated over long period of time and was extended year after year. Six soil profiles were selected where three were representing the cultivated area for almost 60 years and three for less than 10 years. The main criteria of the sampled profiles were determined for physical, chemical and fertility points of view, which were previously classified as Typic Quartzipsamments. The approach of land evaluation applying computer software according to FAO system. The obtained data indicate that the estimated land capability of the representative six profiles were belonging to class C4. The limiting factors were mainly the soil coarse texture, low water retention and consequently low available water fro plants. The poor fertility was also a limiting factor as organic matter and nutrient content had negative impact. The dominated relatively high temperature prevailing in this area contributed to accelerate organic matter decomposition and loss of nutrients. Detailed estimation of land suitability classes for 28 crops applying the determined soil criteria of the studied profiles were recorded. The results revealed that the land suitability for crops of the study area could be grouped into three categories. The first category was the suitable class which included peanuts, figs, date palm, olive, grapes, potatoes and tomatoes. The second category was the moderately suitable class that comprised citrus, sugar beet, sunflower, alfalfa, pepper and watermelon while the third category was the marginally suitable which mainly included wheat, barley, maize, cotton and sugarcane. Many of the strategic crops were found marginally suitable due to the prevailing limiting factors of these reclaimed areas which characterized by coarse texture and poor fertility.The variations in the suitability classes between the old cultivated area and the recent ones were not clearly detected due to the similarity of soil characteristics. However, another criteria may be required to be introduced in the suitability system to obtain the slight changes in the crop productivity.

Keywords:Cultivation period, reclaimed sandy soils, land capability for agriculture, land suitability for crops.

INTRODUCTION

Egypt has started land reclamation since the thirties of the last century where, it was and still is the only way for agricultural territory expansion of the country to confront the accelerating increase of population which consequently creates a great pressure on increasing the agricultural production. Therefore, Hanne Kristine Adriansen (2009) stated that reclamation of the desert appears to be a compulsory action in the light of population growth and increased congestion in the Nile Delta and Valley. Land reclamation nowadays is on the top of the Egyptian Government agenda in order to overcome the overwhelmingly unfavorable population to land ratio, (Springborg, 1979 and Bush, 2007).

The reclaimed land was about 48,000 hectare (200,000 fed.) (feddan = 4200.83 m^2) during the period 1932 – 1952 and from the year 1953 to 1959 the reclaimed area reached about 33,100 hectare (78,800 fed.) in different localities including El-Tahrir District, El-Beheira Governorate. Generally, after the 1952 Revolution large areas of almost 383,115 hectare (912,000 fed.) in the Nile Delta and Valley, the Oases and the desert fringes were reclaimed up till 1970 (Hanna and Abdel-Ghani Osman, 1995). However, about 30% of that area is still under marginal productivity.

The western desert soils are dominated by quartz particles that originated from the erosion of sandstones, (FAO, 1979). Thus, it is worth to mention that the desert sandy soils of Egypt have multifarious limitations from agricultural point of view. These limitations include low water retention due to its poor content of fine earth particles and consequently less water availability; low nutrient elements content; fertilizers loss especially nitrogenous ones; and occasionally exposure to wind and water erosion.

Asgari, et al., (2013), assessed the effect of plantation of two well-adapted species to desert environment, Atriplex and Haloxylon. They found that planting the severe sandy decertified reclaimed land with these two species significantly increased soil organic carbon content and consequently improved the soil properties.

Bakry, et al., (2009) carried a field experiment to improve maize production in a sandy soil poor in nutrient bearing capacity and is partially not capable to retain neither soil moisture nor nutrients for the growing plants and soil organisms. The soil was classified as Typic Torripsamments, having a marginally suitable class for crops with both soil texture and gypsum as effective limitations for soil productivity. They applied N, P and K as macronutrients and Fe, Mn, Zn and Cu as micronutrients. Then their results proved that maize yield showed a positive response to all the applied treatments. Moreover, they noticed that the foliar spray with both micronutrients and humic acid, chicken manure, seed inoculation had a positive effect due to enrich macro and micronutrients as well as organic and bio substances that are essential to plant growth and activating the bio-chemical processes in plants, which lead to improve the grain yield and its quality under the prevailing conditions of the experimental soil.

Land evaluation has been defined as an assessment of land use performance for specific purposes, (FAO, 1985). The measured or estimated land characteristics are to be matched the requirements of the desired land use type to determine the suitability of the land for the given land use.

Sys, et al., (1991) reported two ways of land suitability; limitation (qualitative) and parametric (quantitative) methods. The parametric approach consists of numeral rating of the different limitation levels of land characteristics in a numerical scale from a maximum of 100 to a minimum value. de la Rosa and van Diepen (2002), demonstrated the different qualitative and quantitative aspects as well as the quantitative systems, methodologies, modellings and automated applications of land evaluation. They stated that in order to fit the potentialities and limitations of a land unit, the changing land use and management practices must be based on land evaluation results to estimate its suitability and vulnerability. A detailed crop specific land evaluation method is proposed by Sys et al., (1993a), and the crop requirements with regard to climate, landscape and soil conditions given by Sys et al., (1993b).

Many computer soft wares for land evaluation have been developed based on the method presented in the Framework for Land Evaluation of FAO (1976), which allows to build expert systems to evaluate land taking into account local conditions and objectives. The Agriculture Land Evaluation System for arid and semi-arid regions, ALES-Arid software, is one of the developed approaches adopted to the condition of the soils under arid climatic areas (Ismail et al., 2001).

Labib, et al., (1993) evaluated the suitability of different regions in Egypt for wheat growing and found that the studied regions have similar and highly suitable climatic conditions. However, the soil suitability indices differ from one region to another according to the soil characteristics.

Among those studied areas is the Delta fringes and their suitability indices are ranging between 36 and 38 for wheat (fairly suitable class, N1), due to the coarse soil texture where the soils are classified as Typic Quartiz psamments.

Another aspect by Ghabour et al., (1994), who reported that distinguishing between the suitability indices of the cultivated desert land and the virgin desert land is a difficult task as they are numerically quite similar. They attributed the obtained results to the soil coarse texture and the low fertility status; because of the lack of organic matter content of the studied soils even after cultivation. Therefore, a new rating for the organic carbon content of the sandy soils under arid condition was proposed.

The investigated area is located in one of the early desert reclaimed areas in Egypt called Modriat El-Tahrir, El-Beheira Governorate.

However, it is cultivated over a long period of time where it seems that the reclamation and cultivation activities are continuing and consequently, newly reclaimed areas are added year after year. The selected sites, therefore, represent old, for more than 60 years, and recent, for less than 10 years, cultivated land.

The main objective of the current study is to assess the changes in the land capability for agriculture and the land suitability for some crops of a selected area of Modriat El-Tahrir as a result of the cultivation period.

MATERIALS AND METHODS

The study area is situated at almost 170 km northwest of Cairo along the Cairo-Alexandria Desert Road, and belongs to MarkazBadr in the southern region of Modriat El-Tahrir, El-Beheira Governorate (Fig. 1). The area is characterized by annual minimum temperature of 12°C, maximum of 35°C and mean of 22°C. The soils of the study area are classified under the subgroup of Typic Quartzipsamments, (Amal Aziz, 2012).

Six soil profiles were selected, profiles 1, 2 and 3 were of old cultivated area for periods between 60 and 40 years while profiles 4, 5 and 6 were of relatively recent cultivated area for periods between 10 and 5 years, (Fig. 2).

The soil samples representing different layers were air-dried, sieved through 2 mm sieve and then were analyzed for grain size distribution. The soil salinity status as electrical conductivity, the pH values, total carbonates, organic matter content, total N, P and K contents and CEC as essential soil criteria were determined according to SOIL SURVEY STAFF (2014).

The land capability and suitability for 28 different crops were assessed using ALES-Arid software (Ismail et al., 2001). According to Abd El-Kawy et al., (2010), ALES-Arid input data consists of soil physical, chemical and soil fertility properties as well as irrigation water quality and climate data.

Figure 1: Location of Markaz Badr, Modriat El-Tahrir, El-Beheira Governorate, Egypt

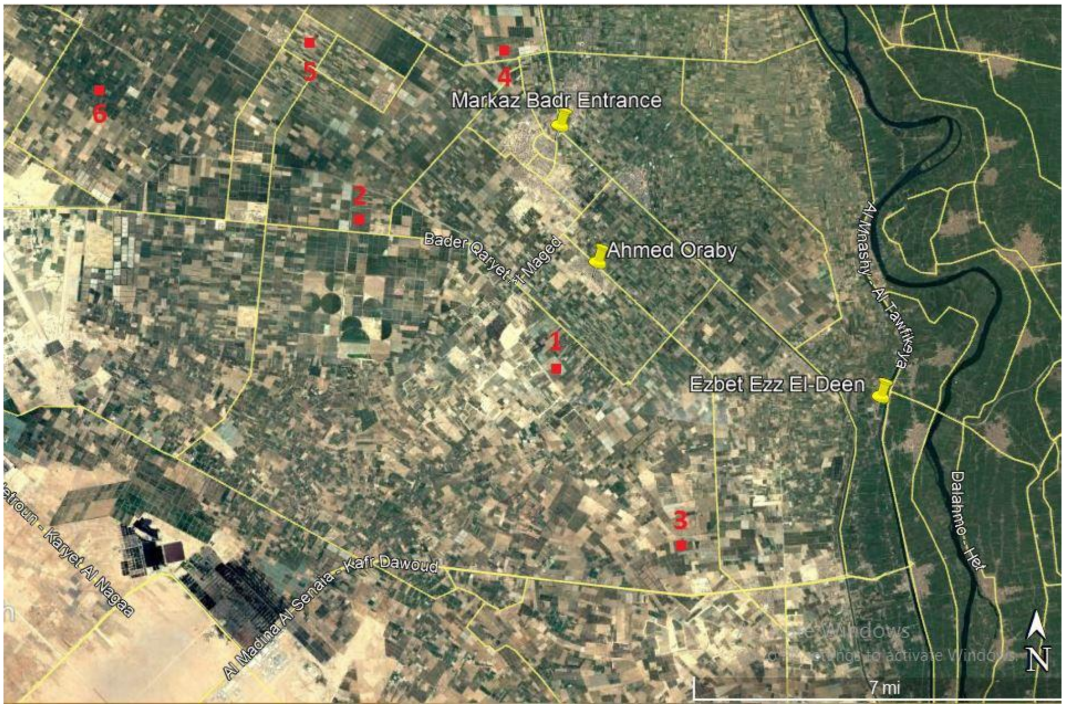

Figure 2: The study area and location of the studied soil profiles

Table 1: Land capability and suitability classes and indices according to ALES-Arid (Ismail et al., 2001).

Land capability categories			Land suitability categories		
Class	**Definition**	**Index**	**Class**	**Definition**	**Index**
C1	Excellent	100-80	S1	Highly suitable	100-80
C2	Good	<80-60	S2	Suitable	<80-60
C3	Fair	<60-40	S3	Moderately suitable	<60-40
C4	Poor	<40-20	S4	Marginally suitable	<40-20
C5	Very Poor	<20-10	N1	Currently non-suitable	<20-10
C6	Non-Agricultural land	< 10	N2	Permanently non-suitable	< 10

These data have to be transformed into weighted average values for each soil property related to a particular soil profile according to the following: a) for each soil profile, the number of soil horizons (layers), the thickness of each horizon and the total soil depth, b) the weighted average value (av) for each parameter (soil property) belonging to each soil profile is calculated according to the following equation (Eq. 1):

$$av = \left(\frac{\sum_{i=1}^{n}(v_i t_i)}{T}\right) \quad (1)$$

where, vi is the soil property value relating to soil horizon i, ti is the soil horizon thickness, n is the number of horizons within a soil profile, and T is the total soil profile depth.

Based on the matching between weighted average values of soil parameters and suggested ratings coded within the model, the capability index and limitation for each parameter was estimated and the index gets a value from zero to 100%. The parameter is considered to be a limiting factor if its index gets a value less than 50%. The estimated indices are used by ALES-Arid to calculate three major land capability indices; soil physical index, chemical index, soil fertility index, and water irrigation index, according to equations 2 and 3:

$$Log(MI) = Log(I_1 I_2 I_3 \ldots)/n \quad (2)$$

$$MI = antLog(MI) \quad (3)$$

where, MI is the major index, I1, I2, I3 are the inner estimated indices and n is the number of the inner indices used for the major index calculation.

After calculating the three major land capability indices, the model computes the final land capability index from the three major indices. Finally, the model determines the land capability classes according to the suggested capability categories as well as their corresponding limitations. Table 1 shows the capability classes and the corresponding indices according to ALES-Arid evaluation system. Land suitability indices, classes and limitations for 28 crops were calculated according to the match between the standard crop requirements (internal coded data within the model) and various soil parameter levels. The land suitability class is identified by assigning each land suitability index to confined category (Table 1).

RESULTS

Soil Characteristics

The soils of the study area are sandy desert reclaimed land with sand or coarse sand fractions that reached almost between 99.9 and 98.23 %, (Table 2), in all profiles and layers while the fine mineral particles; clay and silt, were between 0.10 and 1.77 %. These obtained results showed that the long term cultivation of the soils represented by profiles 1, 2 and 3 had no impact on increasing the soil fine textured fractions. Thus, these soils could be characterized by low water retention and consequently less available water due to their coarse texture. In this respect, Sys and Riquier (1980) explained that texture is one of the most soil characteristics where it remarkably influence important soil properties as soil water availability, infiltration rate, drainage and tillage conditions. The effect of texture may be modified by structure, nature of clay mineral and organic matter content.

The CEC values of the soil surface layers (Table 2), showed some differences between old (11.8 – 9.5 cmolkg^{-1}) and recent cultivated reclaimed land (8.0–5.5 cmolkg^{-1}). This minor variation could be attributed to organic matter addition through the cultivation practices. Although the differences are not pronounced, but in sandy soils which originally have low CEC values, such differences may indicate a slight soil fertility improvement. However, it is still considered as limiting factor. Generally, the investigated soils were non- to slightly saline soils, (Table 2). Nevertheless, the old cultivated reclaimed land constituted mostly non-saline soils while recent cultivated newly reclaimed area was slightly saline soils (profiles 5 and 6). This particular difference may be due to the long term use of the old cultivated reclaimed land and consequently the continuous leaching of salts from their soil profile. The ESP values refer to sodicity of the studied profiles, even in their different layers. However, due to the low content of the soil fine particles; clay and silt, the current sodicity would not affect the cultivation of such land.

The organic matter content of the studied soils was low where it varied between 0.17 and 0.85% (Table 2). These values had resulted in lowering capability class of the studied soils and being a limiting fertility factor.

The total nitrogen, phosphorus and potassium contents of the old cultivated reclaimed land (Table 2) exceeded their correspondents of the recent cultivated reclaimed land. This could be a direct effect of the long term of cultivation of the studied area. This may contribute in raising the fertility status.

The analytical results in table 3 showed that the water is of high quality for irrigation.

Land Evaluation Assessment

Land Capability Classification

The obtained data (Table 4) showed that most of the soils in the study area were belonging to land capability class poor (C4). The limiting factors were found to be the soil texture and water availability. CEC was also a limiting factor for most of the studied soils. Both recent and old cultivated soils were placed in class fair (C3) of soil fertility due to the very poor organic matter content. Coupled with low soil mineral fine particles mainly; the clay and silt fractions, the nutrient elements retention was remarkably weak which in turn affected the land potentiality. However, the irrigation water was classified into class excellent (S1).

Land Suitability Classification

The land suitability for crops of the studied soils are recorded in table 5. The soil performance for crop cultivation could be grouped into three major categories. The first category represents the suitable class for crops including peanuts, figs, date palm, olive, grapes, potatoes and tomatoes. However, all of the soils have texture limiting factor beside available water only in profile no. 5 for these crops.

The second category contains the moderately suitable class for crops mainly; citrus, sugar beet, sunflower, alfalfa, pepper and watermelon. These crops under the actual soil conditions would suffer from both texture and water availability as limiting factors which in turn would decrease their produced yields.

Table 2: Main soil characteristics for land evaluation assessment.

Profile no.	Cultivation period	Depth cm	Physical characteristics			Chemical characteristics						Fertility characteristics			
			Sand %	Silt+Clay %	Texture class	pH	EC dS/m	Exc. Na^+ $cmolkg^{-1}$	ESP	CEC $cmolkg^{-1}$	$CaCO_3$ %	OM %	Total in ppm		
													N	P	K
1	Old cultivated area	0 – 40	98.58	1.42	cS	7.58	0.60	2.5	15	11.8	0.47	0.85	680	229	580
		40 – 70	99.83	0.17	cS	7.74	0.48	1.0	14	7.3	0.31	0.42	432	187	540
		40 – 150	99.78	0.22	cS	7.75	0.27	1.0	17	6.0	0.31	0.20	359	83	240
2		0 – 40	98.74	1.26	S	7.50	1.72	2.5	21	11.7	0.47	0.94	423	375	590
		40 – 100	98.23	1.77	S	7.60	0.50	2.3	21	11.0	0.31	0.32	393	167	790
		100 –150	99.31	0.69	S	7.53	0.93	1.8	20	9.2	1.56	0.17	454	146	620
3		0 – 50	99.06	0.94	S	7.65	0.50	1.4	15	9.5	0.15	0.78	653	208	370
		50 –150	99.79	0.21	S	7.53	1.06	1.5	19	8.0	0.31	0.33	484	125	230
4	Recent cultivated area	0 – 20	99.00	1.00	S	7.40	2.40	1.1	14	8.0	1.41	0.55	350	104	300
		20 – 70	99.09	0.91	S	7.41	2.71	1.4	19	7.3	3.44	0.21	268	83	160
		70 – 150	99.71	0.29	cS	7.42	2.00	1.0	16	6.2	0.94	0.11	260	62	380
5		0 – 20	99.43	0.57	S	7.51	1.85	1.1	18	6.1	2.19	0.61	333	167	290
		20 – 90	98.86	1.14	S	7.40	2.75	1.3	18	7.3	1.25	0.20	242	146	230
		90 – 150	99.52	0.48	S	7.35	7.42	1.3	19	7.0	2.81	0.15	218	62	320
6		0 – 20	99.90	0.10	S	7.44	3.65	1.0	18	5.5	0.63	0.43	197	135	310
		20 –150	99.85	0.15	S	7.35	3.75	1.0	16	6.2	0.31	0.22	139	95	300

Table 3: Irrigation water chemical analyses.

Chemical characteristic	Ec dS/m	pH	Adj. SAR	Na meq/l	Cl meq/l	B ppm
Irrigation canal water	2.0	7.2	12	5.0	6.0	0.0

Table 4: Land capability classification and limitations of the studied desert soils.

Profile no.	Land Capability		Fertility		Water
	Class	Limitation	Class	Limitation	Class
1	C4	t, aw	C3	om	S1
2	C3	t, aw, cec	C3	om	S1
3	C4	t, aw, cec	C3	om	S1
4	C4	t, aw, cec	C3	om	S1
5	C4	t, aw, cec	C3	om	S1
6	C4	t, aw, cec	C3	om	S1

t=texture (clay content) aw=available water cec=CEC

Table 5: Land suitability classification for crops and limitations of the studied desert soils.

Crop	Profile no. 1	Profile no. 2	Profile no. 3	Profile no. 4	Profile no. 5	Profile no. 6
Peanuts	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S2 (t, aw)	S2 (t)
Figs	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S2 (t, aw)	S2 (t)
Date palm	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S2 (t, aw)	S2 (t)
Olive	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S2 (t, aw)	S2 (t)
Potatoes	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S3 (t, aw)	S3 (t)
Tomatoes	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S3 (t, aw)	S3 (t)
Grapes	S2 (t)	S2 (t)	S2 (t)	S2 (t)	S3 (t, aw)	S3 (t)
Citrus	S3 (t)	S2 (t)	S3 (t)	S3 (t)	S3 (t, aw)	S3 (t)
Sugar beet	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)
Sunflower	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)
Alfalfa	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)
Pepper	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)
Watermelon	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)
Sorghum	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S3 (t, aw)	S3 (t, aw)	S4 (t, aw)
Wheat	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)
Barley	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)
Maize	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Pear	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Sugarcane	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Cabbage	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Banana	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Apple	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw)
Onion	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw, ece)	S4 (t, aw)
Faba beans	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw, ece)	S4 (t, aw, ece)
Soya beans	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw, ece)	S4 (t, aw, ece)
Pea	S4 (t, aw)	S3 (t, aw)	S4 (t, aw)	S4 (t, aw)	S4 (t, aw, ece)	S4 (t, aw, ece)
Cotton	S4 (t, aw, temp)	S4 (t, aw, temp)	S4 (t, aw, temp)	S4 (t, aw, temp)	S4 (t, aw, temp)	S4 (t, aw, temp)
Rice	NS2 (t)	NS2 (t)	NS2 (t)	NS2 (t)	NS2 (t)	NS2 (t)

t=Texture (clay content) aw=Available water ece=EC temp=Temperature

Suitable (green) — moderately suitable (yellow) — Marginally non-suitable (red) — permanently non-suitable (dark red)

The third category includes the marginally suitable class for crops. The crops which could be marginally produced from cultivating the investigated soils are unfortunately the strategic crops such as wheat, maize, cotton and sugarcane as well as others that strategically are of less importance whereas, the land is permanently non-suitable for rice cultivation. The limiting factors of this group of soils are texture, available water, salinity and temperature.

Ghabour et al., (1994) got nearly the same results for almost similar soil characteristics which were classified as Typic Quartzipsamments. They reported that the investigated soils were very suitable for groundnuts, carrots and potatoes, moderately suitable for millet, sunflower, beans, watermelons and tomatoes while marginally suitable for wheat, clover, maize, sorghum and onions.

CONCLUSION

The land capability of the study area was belonging to class C4 as it hampered by weak soil structure, low water-holding capacity, low organic matter content and low inherent fertility. The land suitability classes were grouped in three categories. They were found to be suitable for peanuts, potatoes, tomatoes, date palm and grapes; moderately suitable for citrus, sugar beet, sunflower, alfalfa, pepper and watermelon and marginally suitable for wheat, barley, maize, cotton and sugarcane. The land suitability limitations were mainly texture, available water and occasionally salinity and temperature.

The abovementioned results revealed clearly that the investigated reclaimed desert area had not agriculturally improved even after long term of cultivation. Thus, the production per unit area of some crops may cost much more than the same unit which can be produced from old fertile soils in Nile Delta and Valley or other desert reclaimed area under good management processes.

The current study recommended that some of the reclaimed desert sandy soils have to be undergone proper and nonconventional management measures in order to ensure the improvement of their potential agricultural capabilities. Such management policy may encompass organic manure addition and nutrient application programmes, conservation practices to avoid soil compaction, salinity and water table rise on the long turn.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest”.

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AUTHOR CONTRIBUTIONS

Ghabour analyzed and discussed the obtained results, carried out the land evaluation assessment and wrote the manuscript. Aziz and Rahim carried out the field work as well as the laboratory analyses and contributed in discussing the results.

All authors read and approved the final version.

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