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Soil Characterization and Estimation of the Current and Future Productivity of the Faculty of Agriculture Farm, Sohag University, Egypt

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ABSTRACT

This study aimed to characterize the soils and estimate the current and future land productivity in a part of western Sohag desert. Fourteen soil profiles represented the area where soil samples were collected layer-wise from each. Samples were prepared and analyzed for their physico-chemical and fertility parameters using standard methods of analysis. Soil data were put in models of current and future productivity estimation. Results revealed that, study area was deep (>100cm), well drained, coarse textured, slightly to moderately calcareous ($CaCO_3$=4.96% to 11.05%), slightly alkaline (pH=8.06 to 8.37), slightly to moderately saline (EC_e=1.16 to 7.00 $dS.m^{-1}$), with low moisture (<5%), organic matter (0.27% to 0.92%), and cation exchange capacity (4.7 to 15.7 cmol(+) kg^{-1}). Soils were low to medium in total nitrogen (161 to 533 $mg.kg^{-1}$), low to medium in available phosphorus (3.21 to 8.12 $mg.kg^{-1}$) and low in available potassium (127 to 195 mg kg^{-1}), available micronutrients varied between deficient and adequate for cropping requirements. The current productivity situation is extremely poor due to low agricultural activities and poverty in soil content of moisture, organic materials and clay fractions. Improvement processes should be followed such as organic fertilizers addition and dredged clay materials to the soil surface layer for enhancing the land productivity by about 15 to 17 times. The integration of soil surveying, sampling, analysis, and productivity estimation found to be an effective tool for predicting land productivity. These data can be utilized for better land use management, planning for land reclamation, and improving the agricultural productivity.

***Keywords*: Sohag, soil characterization, current productivity, future productivity, soil fertility.**

INTRODUCTION

Egyptian Government plans for an agricultural expansion to reduce the problems linked with food security, increasing population and urban sprawl on the agricultural lands. Moreover, Egypt's Vision 2030 for sustainable development focuses on the obstacles facing the development plans (Ministry of communications and information technology (MCIT), 2020). Some of these challenges are related to land resources scarcity including land, water, energy, environmental degradation, beside the shortage of available resources to the Egyptians. Geographically, Egypt covers about a million square kilometers. The population lives on about 5% only of this area. Unfortunately, no accurate statistics for agricultural lands, urban sprawl on old cultivated lands (Omran and Negm, 2020). Therefore, newly cultivated areas start expanding East and West to fulfill people's needs for more living spaces as well as to reduce the pressure on alluvial lands in the Nile Valley and Delta. Nowadays, Egypt as several countries around the world is facing a problem of managing the natural resources because of climatic changes. The degradation of some Egyptian soils is another main challenge which affects directly or indirectly on the reduction or loss of lands' capability and productivity. Furthermore, Egypt is affected by desertification and drought which mainly caused by human activities, climate change, mismanagement of soil and water, speedy urban encroachment on the cultivated lands and water shortage as Egypt's share of water is constant, but consumption is increasing dramatically (Elbeih, 2021). Therefore, the ideal way for better agricultural production is to reclaim new lands. Egyptian Government focused on cultivating large areas in Eastern and Western Deserts. The Ministry of Planning and Economic Development (2021) reported that these lands have many disadvantages which reduce their capability and productivity such as soil coarse texture; difficulty of leveling; absence of the organic materials; very low content of macro and micro nutrients; presence of soluble or less soluble salts; low water and nutrients holding capacity; wind movement; very low precipitation, high temperature and low humidity; and formation of limestone layers in calcareous soils. However, for achieving a successful new lands' reclamation, some policies should be followed such as application of fertilizers in specific forms and through irrigation systems. The addition of organic materials and soil amendments is compulsory to ameliorate soil characteristics and increase soil capability and productivity. The good infrastructure (e.g., energy, roads, social services, and education) may encourage agricultural investors to cultivate new soils and improve the agricultural growth. So, Land evaluation is an effective tool for strategic land use planning (George, 2015). Land capability is the potential of the land for use in specified ways, or with specified management practices (Mohamed, 2002). Soil capability classification help in specifying major land problems or limitations and give an indicator for land management requirements (Manikandan et al., 2013). Soil fertility evaluation is done using specific physico-chemical properties which refers to the ability of soil to sustain nutrients required by plants in adequate quantities and correct

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proportions (Jin et al., 2011). It is one of the components that control its productivity potentials, and the status of this fertility is strongly influenced by management practices (Johnson et al., 2000). Evaluating the current and potential land productivity situation is very important for better land management and understanding the land limitations as well as it gives guidelines for agricultural stake holders to achieve a success in reclamation or land conservation.

Sohag Governorate is one of agricultural Upper Egypt's Governorates. Recently, large pieces of new lands are reclaimed and cultivated (e.g., West Tahta; West Geheina; Wadi Qena; New Akhmim; etc.). Many researchers studied the soils of western part of Sohag as a promising area where can be reclaimed and utilized for agricultural purposes. For example, El-Sayed et al. (2020) investigated the area of Wadi Tag El-Wabar, south-western of Sohag governorate, Egypt. They found that these soils have a texture ranging from medium texture (loam) to extremely gravelly sandy loam texture. Low soil organic matter content (0.12-0.44%) is there, while total calcium carbonate ($CaCO_3$) of the area varies from low (4.32%) to very high (63.36%). They reported that these soils were slightly (pH=7.54) to strongly (pH=8.9) alkaline and the EC_e values of the studied area vary between non-saline (0.47 dS m^{-1}) to strongly saline (105.95 dSm^{-1}). Exchangeable sodium percentage (ESP) of these soils ranges from 1.48 and 20%. Also, the observed cation exchange capacity (CEC) was low that ranged from 2.80 to 12.31 cmol(+) kg^{-1}. Moursy et al. (2020) characterized some soils of Wadi Qena, East Sohag. They pointed out that these soils were moderately deep to deep in depth, well drained, slightly to strongly alkaline in soil reaction (7.6 - 8.4), slight to moderate saline (3.3- 15.4 dS m^{-1}). The soils were low in organic matter (0.09 – 0.65%), low in CEC (1.5–8.1 Cmol (+) kg^{-1}) and calcium carbonates ranged from (1.2 – 18.2%). The results revealed that the soils were low in available N (1–21 $kg.ha^{-1}$), low in available P (1.0 - 9 kg ha^{-1}), and low to high in available K (105 – 762 kg ha^{-1}). Further, the soils were low in available micronutrients. Other study was carried out in Dakhla Oasis, Western Desert, Egypt by Fadl and Abuzaid (2017), they found that the soils of the study area are gently sloping (2.72-2.76%) and moderately deep to deep (70-110 cm). Soil texture is gravelly and very gravelly sandy loam. 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} soil and from 52.32 to 61.46 g kg^{-1} soil, respectively. Soil CEC ranged from 7.80 to 11.60 cmol(+) kg^{-1} soil. ESP varied from 2.21 to 8.92 %, indicating none-sodic soils. From the previous introduction, this study aims to: (a) characterize some soils of Western Sohag Governorate; and (b) evaluate the current and the future land productivity of a part of Sohag Western desert.

MATERIALS AND METHODS

1. Study area

The study area is a part of the newly reclaimed farm of Faculty of Agriculture, new campus of Sohag University, El-Kawamel, Sohag, Egypt with a total area about 40 fed. It lies in the western part of Sohag governorate between 26°28'17.76", 26°27'54.75" N and 31°40'13.11", 31°40'24.28" E, Figure (1) showed the location map of the study area. The climate of this area is characterized as dry climate along the year. The temperature varies from 8°C to 39°C and is rarely below 5°C or above 43°C. Non-significant seasonal variation in the frequency of rainfall. The average wind speeds are about 8.5 knots with maximum records for 10.0 k knots. Table (1) and Figure (2) demonstrated the climatic condition of 2021 year of the study area. According to Thabit (2012), the reclamation steps in the study area started in 2000 by establishment of sprinkler and drip irrigation systems and addition about 30 cm of dredged clay materials from the irrigation canals to the soil surface as a soil amendment to improve soil physical properties and the availability of the essential nutrients for plant growth. The cultivation and agricultural practices continued in the study area to present, the major of the study area is annually cultivated with wheat and alfalfa with application of mineral fertilization and organic amendments (farmyard manure), another part of the study area was cultivated with grape. The irrigation water source depends on the Nile water from the near canal. Moreover, the salinity of the used water is not exceeding 0.5 dS m^{-1} over the year.

2. Soil sampling

A Total number of 14 soil profiles were selected to represent the study area in 2021. Profiles No 1, 2, 3, 5, 6, 7, 12 and 13 were sampled from areas cultivated with wheat and irrigated with sprinkler irrigation, while the profiles No 8, 9 and 11 were collected from areas cultivated with alfalfa under sprinkler irrigation. Moreover, the profile No 10 was sampled from area cultivated with grape under drip irrigation, but the profiles No 4 and 14 were collected from uncultivated area to present the soil status of the study area before reclamation and cultivation. Latitudes and longitudes of studied profiles were recorded using GPS "Garmin–eTrix" under WGS84 coordinate system as shown in Table (2). Soil profiles were exposed, and four soil samples were collected carefully from each profile at depths (0- 25, 25-50, 50-75 and 75-100cm).

Table 1. The average of climatic condition of the study area in 2021 (https://weatherspark.com/).

Average	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature	14	16	20	25	30	32	33	32	30	26	20	16
Wind Speed	7	7.4	8	8.4	9.1	10	9.5	9.4	9.3	8	7.2	7
Precipitation	0.1	0	0	0	0	0	0	0	0	0.1	0.1	0

Table 2. Geo-coordinates of soil profiles in decimal-degrees system.

Soil profiles	Latitudes (N)	Longitudes (E)
P1	26°.4683	31°.6729
P2	26°.4681	31°.6718
P3	26°.4673	31°.6721
P4	26°.4656	31°.6723
P5	26°.4687	31°.6704
P6	26°.4670	31°.6705
P7	26°.4674	31°.6731
P8	26°.4665	31°.6714
P9	26°.4665	31°.6728
P10	26°.4692	31°.6722
P11	26°.4701	31°.6706
P12	26°.4710	31°.6715
P13	26°.4698	31°.6714
P14	26°.4656	31°.6707

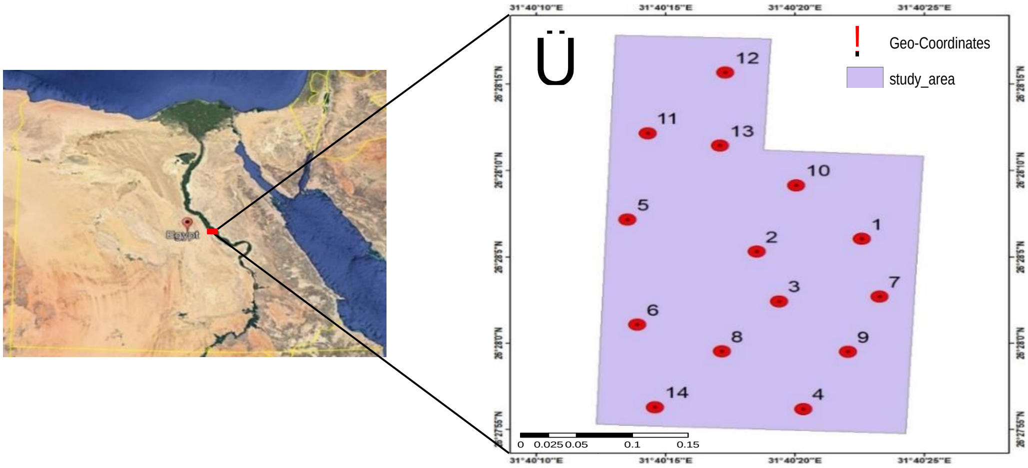

Figure 1. The location map of the study area.

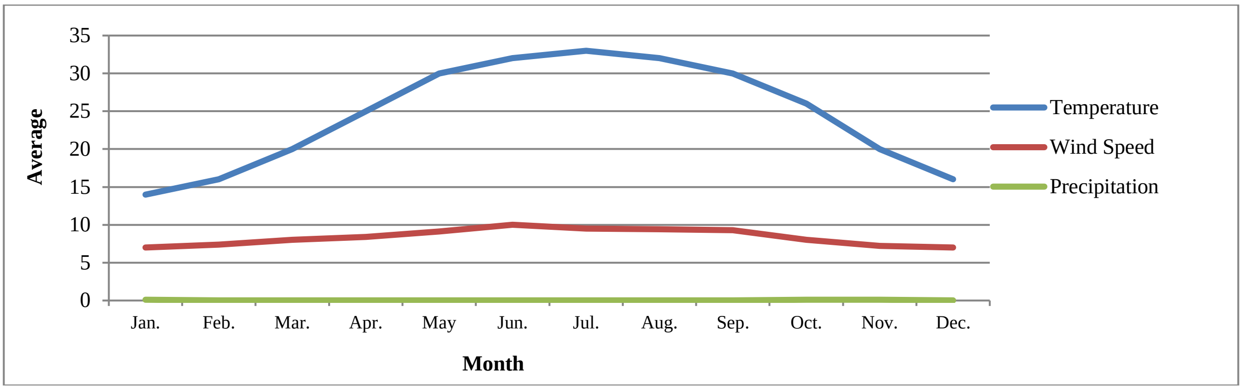

Figure 2. The average of climatic condition of the study area in 2021.

3.Soil Samples preparation and laboratory analysis

Soil samples were shifted to the soil laboratory for preparation and analysis. Soil samples were air dried for two days, then crushed and passed through 2 mm sieve. Soil material (<2 mm) was utilized for a determination of main soil physical and chemical properties. Soil reaction (pH) was measured in (1:1) soil to water suspension by pH-meter with a glass electrode (pH 211, Microprocessor pH meter, HANNA Instruments). Electrical conductivity (EC_e) was measured in the saturated soil paste extract using the electrical conductivity meter (Orion model 150, USA). Soluble cations and anions were determined in the saturated soil paste extract, where the soluble sodium (Na^+) and potassium (K^+) were measured by flame photometer method (Hesse, 1998), while the calcium (Ca^{+2}) and magnesium (Mg^{+2}) were titrated using ethyline-diamine tetra acetic acid (EDTA) solution (Richards, 1954). Soluble bicarbonates (HCO^-_3) were titrated by HCl (Richards, 1954), while the soluble chloride (Cl) was titrated by silver nitrate (Jackson, 1973), furthermore, the soluble sulfate (SO^{-2}_4) was determined by turbidity method using spectrophotometer (Baruah and Barthakur, 1997). Particle size distribution was done by international pipette method (Jackson, 1969). Total calcium carbonates were estimated volumetrically using Colins's calcimeter (Jackson, 1973). Soil organic matter content was determined by walkley and black method (Jackson, 1973). The cationic exchange capacity (CEC) was measured using 1 M sodium acetate solution (pH = 8.2) for saturation and 1 M ammonium acetate solution (pH=7) for replacing (Baruah and Barthakur, 1997). Regarding soil content of macro nutrients, total Nitrogen was determined using modified Kjeldahl distillation procedure (Jackson 1973). Available phosphorus was measured colorimetrically by spectrophotometer after extraction with 0.5M $NaHCO_3$ (pH=8.5) as described by Olsen et al. (1954). Available potassium was extracted by ammonium acetate (pH=7) and measured by flame photometer (CL 378 - ELICO) (Carson, 1980). Available micronutrients (Fe, Mn, Zn and Cu) were extracted using DTPA solution (0.005M, pH=7.3) according to Lindsay and Norvell (1978) and then the DTPA-extractable micronutrients measured by ICP Spectrometer (iCAP 6000 Series - Thermo Fisher Scientific Company). The used data of each soil profile was transformed into a weighted mean (Tables 3 and 5). Calculation of the mean weighted value for each soil property (V) of the profile calculated by multiplying the summation of (vi) for each horizon by horizon thickness (ti) divided by the profile depth (T) according to equation (1).

$$V = \sum_{i=1}^{n} \frac{(vi \times ti)}{T} \quad (1)$$

4. Statistical analysis:

The descriptive statistical analysis was done for soil laboratory analysis data using Microsoft Excell (2010) software included mean, standard error, median, standard deviation, variance, kurtosis, skewness, range, minimum and maximum.

5. Estimation of current and future land productivity

The current and future productivity indices were computed by adopting the procedure of (Riquier et al., 1970). Nine soil factors are required for determining soil productivity, drainage (D), depth (P), soil moisture content (H), texture (T), average nutrient content (N), organic matter content (O), soluble salts content (S), reserves of weatherable minerals (M) and soil cationic exchange capacity (A). Each soil factor was rated on a scale between 0 and 100. After that, the obtained percentages were multiplied to calculate the productivity index (PI) as in the following equation (2):

$$PI = H\times D\times P\times T\times S\times A\times N\times M\times O. \quad (2)$$

The result will be under one of five productivity classes, namely excellent, good, average, poor, and extremely poor. After improving soil characteristics which considered as limitations of productivity, the potentiality index (P\I) of the estimated future productivity could be calculated using equation (3). The improvement coefficient (IC) of land productivity (P\I /PI) was estimated as described in equation (4).

$$P^{\backslash}I = H\times D\times P\times T\times S\times A\times N\times M\times O+10\%. \quad (3)$$

$$IC = \text{Potentiality Index } (P^{\backslash}I) / \text{Productivity Index (PI)}. \quad (4)$$

RESULTS AND DISCUSSION

1. Physico-chemical characteristics of the studied area

The weighted mean (W) data of soils physico-chemical properties of all soil profiles as well as descriptive statistical analysis of the corresponding soils were presented in Table (3) and Table (4), respectively. The obtained data revealed that soils were alkaline with weighted mean of pH values ranged from 8.06 to 8.37. The soils were characterized with low to moderate salinity as indicated from EC_e values (1.16 to 7.00 dS m^{-1}). Regarding to the weighted mean of soluble cations and anions, it can be found that Na^+ was the dominant soluble cation in all studied profiles followed by Ca^{+2}, Mg^{+2} and K^+ cations, respectively. Dominant soluble anion in all soil profiles was Cl^- then HCO^-_3 and SO^{-2}_4, respectively. Three soil texture classes (sandy loam, loamy sand and sandy) were recorded for the study area. Soil particle distribution showed a weighted mean of sand content ranged from 86.98 to 92.31% with an average of 80.84%, silt content ranged from 3.54 to 21.22% (average 11.37%) and clay content varied from 4.16 to 11.14% whereas the average was 7.79%. The results indicated that soils of profiles 4 and 14 exhibited higher content of soil coarse particles as compared to other soils which can be attributed to the lowest agricultural practices in these sites. The weighted mean of calcium carbonates in soil ranged from 4.96 to 11.05% with average value of 7.28%. Moreover, highest $CaCO_3$ contents (10.16% and 11.06%) were recorded for profiles 4 and 14, respectively compared to other soils. The soil content of organic matter (OM) was low (0.27 to 0.92%) whereas decreased with soil depth. The low organic materials were due to poor vegetation cover as well as high temperature which increase organic matter decomposition. Soils were low in CEC and decreased with depth which directly related to soil texture. The weighted mean of soil CEC varied from 4.70 to 15.70 cmol (+) kg^{-1} with an average of 10.59 cmol (+) kg^{-1}.

Table 3. Weighted mean (W) of soil physico-chemical properties of the studied soil profiles.

Soil properties	Soil profile (P) No.													
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**
pH (1:1)	8.15	8.11	8.09	8.37	8.19	8.07	8.21	8.13	8.06	8.27	8.19	8.23	8.25	8.22
EC_e (dS m^{-1})	1.53	1.62	1.74	4.76	1.56	1.51	1.42	1.66	1.16	1.88	1.63	1.25	1.32	7.00
Sand (%)	68.98	75.93	74.86	90.82	78.54	78.29	72.63	84.51	82.48	78.84	85.73	81.02	86.86	92.31
Silt (%)	21.22	14.79	15.79	4.86	12.50	15.15	16.23	7.85	9.05	12.39	8.50	10.93	6.36	3.54
Clay (%)	9.80	9.28	9.36	4.33	8.96	6.56	11.14	7.64	8.47	8.77	5.77	8.05	6.78	4.16
Soil texture	SL	SL	SL	S	SL	LS	SL	LS	LS	LS	LS	LS	LS	S
Total $CaCO_3$ (%)	4.96	6.45	7.19	10.16	7.03	5.51	6.99	7.25	7.09	7.71	6.40	8.00	6.15	11.05
OM (%)	0.81	0.60	0.51	0.34	0.70	0.52	0.67	0.92	0.75	0.65	0.72	0.55	0.70	0.27
CEC (cmol (+) kg^{-1})	15.70	12.43	13.67	5.50	11.23	12.43	14.58	9.00	11.07	11.24	8.89	9.49	8.26	4.70
Soluble Na^+ (meq L^{-1})	7.83	8.00	9.35	18.85	8.30	7.43	6.90	7.18	7.19	11.98	8.60	5.43	6.72	32.05
Soluble K^+ (meq L^{-1})	0.77	0.39	0.31	4.83	0.31	0.33	0.26	0.35	0.25	0.23	0.21	0.23	0.50	4.25
Soluble Ca^{+2} (meq L^{-1})	4.50	5.65	5.10	11.75	4.30	4.80	4.55	5.45	3.05	3.90	4.70	4.10	3.55	20.40
Soluble Mg^{+2} (meq L^{-1})	1.95	2.65	3.30	9.13	2.35	2.20	2.50	3.45	2.20	3.10	3.45	2.05	2.10	13.40
Soluble HCO^-_3 (meq L^{-1})	5.65	5.48	10.53	4.05	3.35	3.98	4.88	4.13	6.15	7.23	5.00	4.13	17.93	5.05
Soluble Cl^- (meq L^{-1})	8.05	9.35	9.85	30.73	8.35	9.25	8.45	10.45	6.40	12.10	7.80	6.15	7.35	40.95
Soluble SO_4^{-2} (meq L^{-1})	1.13	1.60	1.40	4.73	2.13	1.65	1.25	1.28	1.10	1.25	1.08	1.48	1.23	8.25

Table 4. Descriptive statistical analysis of soil physico-chemical properties of the studied soil profiles.

Soil properties	Mean	S.E.	Median	S.D.	Variance	Kurtosis	Skewness	Range	Minimum	Maximum
pH (1:1)	8.18	0.02	8.19	0.09	0.01	0.17	0.48	0.31	8.06	8.37
EC_e (dS m^{-1})	2.15	0.44	1.59	1.65	2.73	6.08	2.55	5.84	1.16	7.00
Sand (%)	80.84	1.80	79.93	6.74	45.48	-0.55	0.09	23.33	68.98	92.31
Silt (%)	11.37	1.33	11.66	4.99	24.88	-0.45	0.21	17.68	3.54	21.22
Clay (%)	7.79	0.55	8.26	2.05	4.20	-0.42	-0.47	6.98	4.16	11.14
Total $CaCO_3$ (%)	7.28	0.44	7.06	1.63	2.67	1.54	1.18	6.09	4.96	11.05
OM (%)	0.62	0.05	0.66	0.17	0.03	0.29	-0.53	0.65	0.27	0.92
CEC (cmol (+) kg^{-1})	10.59	0.85	11.15	3.19	10.15	-0.32	-0.33	11.00	4.70	15.70
Soluble Na^+ (meq L^{-1})	10.42	1.88	7.92	7.04	49.52	7.42	2.67	26.62	5.43	32.05
Soluble K^+ (meq L^{-1})	0.94	0.41	0.32	1.53	2.35	3.87	2.28	4.62	0.21	4.83
Soluble Ca^{+2} (meq L^{-1})	6.13	1.23	4.63	4.60	21.12	7.87	2.77	17.35	3.05	20.40
Soluble Mg^{+2} (meq L^{-1})	3.85	0.88	2.58	3.29	10.86	5.68	2.47	11.45	1.95	13.40
Soluble HCO^-_3 (meq L^{-1})	6.25	1.02	5.03	3.81	14.53	7.22	2.59	14.58	3.35	17.93
Soluble Cl^- (meq L^{-1})	12.52	2.73	8.85	10.20	104.09	4.85	2.36	34.80	6.15	40.95
Soluble SO_4^{-2} (meq L^{-1})	2.11	0.53	1.34	2.00	3.99	7.46	2.73	7.17	1.08	8.25

2. Fertility status

The weighted mean data of macro and micro-nutrients content of all studied profiles as well as descriptive statistical analysis of these data were summarized in Table (5) and Table (6), respectively. The soil total nitrogen in the study area was low and ranged from 161.88 to 533.75 mg kg^{-1} with an average of 355.00 mg kg^{-1}. The weighted mean of available phosphorus varied from low to moderate in the studied soils whereas ranged from 3.21 to 8.12 mg kg^{-1} (average 5.92 mg kg^{-1}). Regarding to available potassium, the minimum and maximum weighted mean values were 127.05 and 195.05 mg.kg^{-1}, respectively while average content was 163.15 mg kg^{-1}. The weighted mean of DTPA extractable Fe and Mn ranged from 3.95 to 12.12 mg kg^{-1}(average 8.52 mg kg^{-1}) and from 1.52 to 9.13 mg kg^{-1}(average 5.54 mg kg^{-1}), respectively. while, the weighted mean of DTPA extractable Cu and Zn varied from 0.40 to 1.80 mg.kg^{-1}(average 1.00 mg kg^{-1}) and from 0.81 to 5.4 mg.kg^{-1}(average 2.63 mg kg^{-1}), respectively. According to the proposed sufficiency level of DTPA-extractable micronutrient by Lindsay and Norvell (1978), follow 4.5, 1.0, 0.2 and 0.6 mg kg^{-1} for Fe, Mn, Cu and Zn, respectively. The studied soils were ranged from deficient to adequate for crop production. From the obtained data, it was obvious that the macro and micro nutrients in all soil profiles were having similar ranges of the soil content except profiles 4 and 14. This was due to poor vegetation and non-agricultural practices in these sites. The main reason of the low fertility status of the study area is due to the low soil organic matter content, nutrients and water holding capacity beside thermic climatic conditions.

Table 5. Weighted mean (W) of soil macro- and micro-nutrients of the studied soil profiles.

Soil nutrients (mg kg^{-1})	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
Total N	437.50	393.75	332.50	183.75	428.75	315.00	385.00	533.75	406.88	341.25	310.63	328.13	411.25	161.88
Available P	6.13	4.82	7.10	3.21	7.53	8.12	5.63	6.56	7.16	5.14	4.96	6.02	7.10	3.45
Available K	195.05	157.98	175.68	136.68	167.68	156.75	182.28	163.28	146.30	183.55	150.55	175.05	166.18	127.05
DTPA-Fe	12.12	6.89	10.38	5.03	7.62	8.55	11.36	9.85	9.68	10.10	8.21	7.10	8.38	3.95
DTPA-Mn	5.60	5.29	6.78	1.63	4.35	5.84	9.13	8.12	5.93	6.35	5.76	6.22	4.98	1.52
DTPA-Cu	1.02	0.95	1.05	0.57	0.69	0.88	1.80	1.18	1.32	1.64	0.82	0.84	0.79	0.40
DTPA-Zn	2.62	2.09	2.08	1.07	2.24	2.19	4.18	3.48	2.76	5.40	2.20	2.36	3.36	0.81

Table 6. Descriptive statistical analysis of soil macro and micro nutrients of the studied soil profiles.

Soil nutrients (mg kg^{-1})	Mean	S.E.	Median	S.D.	Variance	Kurtosis	Skewness	Range	Minimum	Maximum
Total N	355.00	26.11	363.13	97.69	9543.23	0.69	-0.51	371.87	161.88	533.75
Available P	5.92	0.40	6.08	1.48	2.19	-0.51	-0.49	4.91	3.21	8.12
Available K	163.15	5.05	164.73	18.90	357.10	-0.30	-0.28	68.00	127.05	195.05
DTPA-Fe	8.52	0.61	8.47	2.30	5.29	-0.12	-0.45	8.17	3.95	12.12
DTPA-Mn	5.54	0.55	5.80	2.07	4.29	0.88	-0.60	7.61	1.52	9.13
DTPA-Cu	1.00	0.10	0.92	0.39	0.15	0.37	0.75	1.40	0.40	1.80
DTPA-Zn	2.63	0.32	2.30	1.19	1.41	1.26	0.83	4.59	0.81	5.40

3.Correlation between soil properties

Data of correlation coefficients of all soil properties was shown in Table (7). From the obtained data, it was clear that high correlation was recorded between the majorities of soil parameters. For instance, pH was highly negative correlated with available phosphorus and CEC with coefficients *r* = -0.63 and -0.57, respectively while positively correlated with calcium carbonates (*r* = 0.57) and low correlated with other parameters. Electrical conductivity was highly correlated with all parameters. Soil particles (sand, silt, and clay) as well as calcium carbonates were very highly correlated with CEC with correlation coefficients *r* = -0.98, 0.96, 0.89, and -0.76, respectively. Total nitrogen was in high positive correlation with organic matter (*r* = 0.93). Available micronutrients were more correlated with organic matter and EC_e, while macronutrients affected much by EC_e, organic matter, $CaCO_3$, and CEC. However, these data could be useful to distinguish the soil parameters' relation.

Table 7. Correlation coefficients of soil properties in the studied soil profiles.

	pH	EC_e	Sand	Silt	Clay	$CaCO_3$	OM	CEC	Total N	Av. P	Av. K	DTPA-Fe	DTPA-Mn	DTPA-Cu	DTPA-Zn
pH	1.00														
EC_e	0.45	1.00													
Sand	0.47	0.64	1.00												
Silt	-0.47	-0.57	-0.98	1.00											
Clay	-0.41	-0.70	-0.90	0.80	1.00										
$CaCO_3$	0.57	0.86	0.69	-0.70	-0.58	1.00									
OM	-0.38	-0.76	-0.43	0.35	0.56	-0.72	1.00								
CEC	-0.57	-0.70	-0.98	0.96	0.89	-0.76	0.49	1.00							
Total N	-0.47	-0.77	-0.51	0.42	0.67	-0.71	0.93	0.55	1.00						
Av. P	-0.63	-0.73	-0.45	0.42	0.46	-0.70	0.53	0.53	0.64	1.00					
Av. K	-0.12	-0.68	-0.82	0.78	0.81	-0.62	0.55	0.78	0.59	0.43	1.00				
DTPA-Fe	-0.43	-0.72	-0.76	0.71	0.77	-0.72	0.73	0.82	0.69	0.55	0.80	1.00			
DTPA-Mn	-0.45	-0.77	-0.62	0.54	0.74	-0.61	0.68	0.68	0.70	0.52	0.67	0.81	1.00		
DTPA-Cu	-0.21	-0.55	-0.57	0.47	0.73	-0.36	0.51	0.62	0.48	0.23	0.60	0.77	0.81	1.00	
DTPA-Zn	0.02	-0.57	-0.39	0.30	0.58	-0.39	0.60	0.42	0.55	0.28	0.66	0.69	0.71	0.86	1.00

4. Estimation of current and future land productivity of the study area

Current land productivity of the study area

Nine soil parameters were utilized for estimating current and future land productivity in the study area. These parameters were adapted with the obtained data of soil laboratory analysis as well as the morphological data of the soil profiles (Table 8). The obtained data revealed that, soil moisture (H) in all soil profiles is below 5 %, well drained (D), and deep (P). The study area was having coarse soil texture (sandy loam, loamy sand, and sandy). Slight salinity (S) was observed in the studied soil profiles, while organic matter was low. Regarding weatherable minerals in subsurface layers of the soil profiles, very low values were recorded. Cationic exchange capacity (A) was low for all soil profiles with base saturation of more than 75 percent.

Each soil parameter of the soil profiles was adjusted and rated in a scale from 0 to 100 as shown in Table (9). All soil profiles were categorized to be under class of (H2c = 40) whereas soil moisture (H) in rooting zone is below wilting point around 9 months of the year. This may because of a very poor agricultural activities occurred in the study area as a newly reclaimed. Soils of the study area were well drained (D4 = 100) with a deep water table and no water-logging of the soil profile. Soil profiles were deep soil with over 90 cm depth and classified as (P5 = 100). Regarding coarse soil texture, low rate of 10 as in class T2b was recorded for all studied profiles. Soil salinity in the study area was slight (S1 = 100). The organic matter in the investigated area was low (O1 = 85), while reserves of weatherable minerals in B horizon very low to Nil as M1 class with a rate value of 85 for all soil profiles. As described by Riquier et al. (1970), CEC of less than 5 cmol (+) kg^{-1} will be classified as (A0) and rated with 85 value, this situation is matched with CEC data of profiles no 4 and 14 of the study area. Other class (A1) with value of 90 is refers to soils with CEC less than 20 cmol (+) kg^{-1} whereas similar to CEC value in other profiles. Base saturation in surface layers of all studied profiles was over 75 percent (N5 = 100). Regarding productivity index (PI), PI5 class was recorded for all studied profiles whereas PI values were below 7 as described by (Riquier et al., 1970). From the brief discussion of current land productivity results, it was obvious that the limitations of land productivity in the study area were mainly the low soil moisture content, coarse soil texture, and poor organic matter. These limitations were resulted from the poor agricultural activities and practices occur in the study area.

Table 8. Characterization of soil profiles of the studied area.

Profile No.	H	D	P	T	S	O	M	A	N
P1	<5	Well	deep	sandy loam	0.039	0.81	Very Low	15.70	<75%
P2	<5	Well	deep	sandy loam	0.033	0.60	Very Low	12.43	<75%
P3	<5	Well	deep	sandy loam	0.039	0.51	Very Low	13.67	<75%
P4	<5	Well	deep	sand	0.070	0.34	Very Low	5.50	<75%
P5	<5	Well	deep	sandy loam	0.037	0.70	Very Low	11.23	<75%
P6	<5	Well	deep	loamy sand	0.031	0.52	Very Low	12.43	<75%
P7	<5	Well	deep	sandy loam	0.032	0.67	Very Low	14.58	<75%
P8	<5	Well	deep	loamy sand	0.032	0.92	Very Low	9.00	<75%
P9	<5	Well	deep	loamy sand	0.022	0.75	Very Low	11.07	<75%
P10	<5	Well	deep	loamy sand	0.040	0.65	Very Low	11.24	<75%
P11	<5	Well	deep	loamy sand	0.031	0.72	Very Low	8.89	<75%
P12	<5	Well	deep	loamy sand	0.028	0.55	Very Low	9.49	<75%
P13	<5	Well	deep	loamy sand	0.026	0.70	Very Low	8.26	<75%
P14	<5	Well	deep	sand	0.096	0.27	Very Low	4.70	<75%

H: Moisture Content (%), D: Soil Drainage, P: Soil Depth (cm), T: Soil Texture Grade, S: Total soluble salts (%), O: Soil organic matter (%), M: Reserves of weatherable minerals, A: Cationic exchange capacity, and N: Base saturation.

Table 9. Actual land productivity parameters.

Profile No.	H	D	P	T	S	O	M	A	N	PI
P1	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P2	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P3	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P4	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (2.60)
P5	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P6	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P7	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P8	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P9	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P10	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P11	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P12	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.60)
P13	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (2.45)
P14	H2c (40)	D4 (100)	P5 (100)	T2b (10)	S1 (100)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (2.45)

H: Moisture Content (%), D: Soil Drainage, P: Soil Depth (cm), T: Soil Texture Grade, S: Total soluble salts (%), O: Soil organic matter (%), M: Reserves of weatherable minerals, A: Cationic exchange capacity, and N: Base saturation.

Future land productivity

Limitations of land productivity were derived from the data of current productivity index. Therefore, for estimating future land productivity, some soil parameter should be improved to enhance the land productivity of the study area. These soil properties which should be enhanced were soil moisture, texture, and organic matter. For improving soil moisture, irrigation of growing plants should be applied continuously in the study area. That meant the agricultural activities must be increased by cultivating the land with suitable crops over the year. The data of soil parameters after improvement were shown in Table (10). These data demonstrated that, soil moisture content after enhancement was changed from (H2c = 40) to (H4c = 90). Furthermore, Soil texture should be improved to be little bit finer by adding organic materials and clayey soil. Soil texture was changed from (T2b = 10) to (T6a = 60) after improvement. Regarding the soil content of the organic matter, the improvement will be achieved by addition of organic materials to the current soil. After that, the organic matter enhanced from (O1 = 85) to be as (O3 = 100). After more addition of clayey soil and organic matter to the surface layer of the study area, CEC must be enhanced (for example, soil profiles 4 and 14 improved from A0 = 85 to A1 = 90). From the future or potential productivity index data of the study area, it was clear that the land productivity was increased after the proposed solutions of soil improvement. For all studied profiles, the value of P\I index was as P\I2 (between 35% and 64%) whereas good productivity class as described by the procedure of (Riquier et al., 1970). The improvement coefficient (IC) of land productivity (P\I /PI) was estimated for all studied soil profiles. The obtained data revealed that the potential soil productivity can be enhanced by about 15, 16 and 17 times for all soil profiles.

Table 10. Potential land productivity parameters after improvement.

Profile No.	H	D	P	T	S	O	M	A	N	P\I	IC
P1	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (41.31)	16
P2	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P3	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (41.31)	16
P4	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P5	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P6	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P7	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P8	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P9	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P10	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (41.31)	16
P11	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P12	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	15
P13	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (41.31)	17
P14	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S1 (100)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P\I2 (39.02)	16

H: Moisture Content (%), D: Soil Drainage, P: Soil Depth (cm), T: Soil Texture Grade, S: Total soluble salts (%), O: Soil organic matter (%), M: Reserves of weatherable minerals, A: Cationic exchange capacity, and N: Base saturation.

CONCLUSION

This study was carried out in western Sohag Desert, where soils were well-drained, deep, and coarse-textured with low moisture content, soil organic matter content and CEC while BS was more than 75%. The actual land productivity index showed extremely poor in productivity of this land. Land management processes are needed to enhance land productivity. Soil moisture content, texture, and organic matter were as productivity limitations in the study area. The potential land productivity can be increased about 15 to 17 times after improvement. The integration of soil surveying, Sampling, laboratory analysis, and land productivity estimation found to be an effective tool for predicting land productivity in the study area. These data can be utilized by decision makers for better land use management, planning for new lands reclamation, and enhancing agricultural productivity.

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توصيف التربة وتقييم الأنتاجية الحالية والمستقبلية لمزرعة كلية الزراعة , جامعة سوهاج , مصر

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الملخص

استهدفت الدراسة توصيف وتقييم إنتاجية التربة الحالية والمستقبلة لجزء من صحراء سوهاج الغربية. تم حفر 14 قطاع تربة ممثلة للمنطقة وتم أخذ أربعة عينات من كل قطاع. تم تجهيز العينات وتحليل الخصائص الطبيعية والكيميائية لها بإستخدام الطرق القياسية للتحليل. وُضعت بيانات التربة بنماذج تقييم إنتاجية الأراضى الحالية والمستقبلية. أوضحت النتائج أن منطقة الدراسة ذات تربة عميقة (أكبر من 100 سم), جيدة الصرف, قوامها خشن (رملى, رملى طميى, طميى رملى), قليلة إلى متوسطة بمحتواها من كربونات الكالسيوم (4,96 – 11,05 %), منخفضة القلوية (8,06 - 8,37), قليلة إلى متوسطة بالأملاح الكلية الذائبة (1,16 – 7,00 ديسيمنز/م), محتوى رطوبى منخفض (أقل من 5%), المادة العضوية (0,27 – 0,92 %), سعة تبادلية كاتيونية بين 4,7 الى 15,7 سنتيمول+/كجم. التربة ذات محتوى قليل لمتوسط من النيتروجين الكلى (161 – 533 مليجرام/كجم) , محتوى قليل لمتوسط من الفوسفور الميسر (3,21 – 8,12 مليجرام/كجم) ومحتوى قليل من البوتاسيوم الميسر (127 – 159 مليجرام/كجم), بينما كانت المغذيات الصغرى الميسرة (الحديد – المنجنيز – النحاس – الزنك) تتراوح بين حد النقص إلى حد الكفاية لإحتياجات المحاصيل. الإنتاجية الحالية لتلك الأراضى ضعيفة جداً بسبب إنخفاض الأنشطة الزراعية وفقر التربة فى الرطوبة والمادة العضوية والطين. أوصت الدراسة بإجراء بعض التحسينات على تلك الأراضى مثل إضافة الأسمدة العضوية والتربة الطينية فى الطبقة السطحية لتحسين إنتاجية الأراضى بمقدار يتراوح بين 15 إلى 17 مرة. يُعد التكامل بين حصر الأراضى وجمع وتحليل التربة ونماذج تقييم الإنتاجية بمثابة أداة فعالة للتنبؤ بإنتاجية الأراضى فى منطقة الدراسة. يمكن إستخدام تلك البيانات بواسطة صناع القرار فى تحقيق إدارة أفضل لإستخدامات الأراضى وفى عملية التخطيط لإستصلاح الأراضى الجديدة و تحسين الإنتاجية الزراعية.

الكلمات المفتاحية: التربة، الانتاجية الحالية، الانتاجية المستقبلية، خصوبة التربة.