Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL
Volume 5, Issue 1, 2022, Pages 226–241

Available online at www.agricuta.edu.eg

DOI: **https://dx.doi.org/10.21608/aasj.2022.253576**

Assessing the influence of soil properties on wheat and sugarcane grown at Aswan, Egypt

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Abstract

Soil properties including soil salinity is of importance for determining crop production. Therefore, the objective of this study was to assess the influence of soil properties (pH, EC, soluble cations and anions, SAR, $CaCO_3$ and OM) on the production of wheat and sugarcane grown at Upper Egypt, Aswan, Egypt. An agronomic classification proposed by Smith and Doran (1996) was used for soil salinity. Forty-eight and twenty-two surface soil samples were collected at depth 0–30 cm for soils cultivated with wheat and sugarcane, respectively. Regarding the area cultivated with wheat plants the soil salinity, according to the measured $EC_{1:1}$ values can be classified to 29.16% of the collected soil samples were none-saline (less than 1.25 dSm^{-1}), and 47.9 % were slightly saline (less than 2.53 dSm^{-1}) with a total of 77.12%. Meanwhile, 10.4%, 2.08% and 10.4 % of the soil samples were saline, strong saline and extremely saline, respectively with a total of 22.88 %. Moreover, the samples collected from sugarcane cultivated soils, showed 19.04% as non-saline, and 38.08% as slightly saline, 38.08% as saline, and 4.76% as highly saline. This indicates that 77.06% of the samples of wheat soil and 57.12% of the samples of sugarcane soil have a safe salinity level but 22.88% of wheat soil samples and 42.84% of the sugarcane soil samples show a hazardous salinity level. Based on the correlation study and multivariate statistical analysis, the wheat grain yield was affected negatively by the soil bulk density, EC, soluble cations of Ca, Mg, Na and K, and anions of Cl and SO_4, SAR, and $CaCO_3$ content. However, the sugarcane yield is negatively correlated with the soil bulk density and positively correlated to the porosity. Finally, it could be concluded that regarding the soil management for the growing wheat and sugarcane at Aswan, Egypt, should consider the soil physical characteristic including bulk density and porosity and chemical characteristics including salinity levels, soil solution composition and $CaCO_3$ content should be taken to consideration.

Keywords: arid land, soil management, soil salinity, wheat tolerance, sugarcane tolerance, multivariate analysis.

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1. Introduction

Among the greatest challenges of the world is the need for more crop production to satisfy the increasing demand of its growing population (Alexandratos and Bruinsma, 2012). For this purpose, knowledge on soil resources and quality is of importance to identify their potentials for agriculture (Wingeyer *et al*., 2015). Soil properties influence soil quality, reflecting on soil productivity and plant growth. In several Egyptian regions, many agricultural areas suffer from the problem of agricultural soil salinization, which represents a great environmental and economic risk. Due to the loss of soil production for many important crops, which would affect the food of humans and animals, soil salinization is one of the outcomes of desertification (Vengosh, 2003). In Egypt, Aswan governorate is characterized by a hot and dry climate in summer and cold in winter. The irrigation water is mainly from the Nile River and agriculture does not depend upon rain. However, soil salinity is one of many problems of the agricultural lands in Aswan governorate, Egypt. The issues of soil degradation and loss of soil fertility arose when the Aswan high dam was constructed. The water table has been rising substantially closer to the surface in various parts of Egypt's Nile valley, causing soil salinity (Khalifa and Moussa, 2017). Additionally, unsustainable agricultural practices could increase the salinity levels of agricultural soils (Vengosh, 2003). Salinity is considered one of the abiotic stresses that affect most of the crops. Salinity limits the stages of plant growth and development and reduces crop production (Akhtar, 2019; Hamzeh *et al*., 2013; Metternicht and Zinck, 2003). Long term and continuous land cultivation may cause degradation and fertility loss of agricultural soils. Therefore, monitoring soil properties is considered of importance for the management of these soils. Few research is known about effects of long-term use and continuous cultivation of Upper Egypt soils on changes in physical and chemical soil characteristics and their influence on soil quality. The multivariate analysis is widely used for assessing soil quality (Nosrati, 2012). Though numerous soil parameters are needed to evaluate soil quality, using principal component analysis is considered one of the most methods to reduce the number of parameters (Chen *et al*., 2013; Firdous *et al*., 2016). Therefore, the main objective of this study is assessing the influence of soil properties on wheat and sugarcane grown at Aswan, Egypt. In this study, factor analysis (FA) and correlation matrix will be applied on the obtained data to identify the most sensitive soil properties for evaluating the soil productivity.

2. Materials and methods

2.1 Study area

The study area is located in Aswan governorate, Egypt: It is between latitude of 22° 00' - 25° 41' North and longitude of 30° 59' - 33 30' East, and is bordered by the New Valley governorate to the west, the Red Sea governorate to the east, Luxor governorate at north the Republic of Sudan at south. The governorate is located 880 km from Cairo and extends for a length of 258 km to the southern border with Sudan.

2.2 Field study, and soil sampling and analyses

Forty-eight and twenty-two surface soil samples were collected at depth 0–30 cm for soils cultivated with wheat and sugarcane, respectively to represent the area cultivated with wheat and sugarcane in Aswan governorate. The soil samples were air-dried, crushed, sieved through a 2 mm sieve and stored for chemical and physical analyses. Particle size distribution was carried out by the pipette method. Hydraulic conductivity coefficient was determined using undisturbed soil cores (Richards, 1954). Bulk density was measured by cylindrical soil core and graduate cylinder fre loss sand. Total porosity was calculated using the particle and bulk densities (Richards, 1954). Soil pH was measured using pH meter in 1: 2.5 of soil to water suspension using a glass electrode (Jackson, 1973). The Electrical Conductivity ($EC_{1:1}$) was measured in 1:1 of soil to water extracts using an EC meter and the EC_e in the soil paste extract (EC_e) was calculated from EC1:1 by multiplying a conversion factor of 3 (USDA, 1954). Calcium carbonate ($CaCO_3$) content was measured using the calcimeter method (Jackson, 1967). Soluble sodium (Na) and potassium (K) were measured by flame photometer, while soluble calcium (Ca) and magnesium (Mg) were determined volumetrically by EDTA titration method (Jackson, 1973). Soluble anions: chlorides (Cl) were measured by the titration with standard solution of $AgNO_3$. Soluble sulphates (SO_4) were measured using the turbidimetery method (Jackson 1973). The soluble carbonates (CO_3) and bicarbonates (HCO_3) were estimated by the titration with HCl. The organic matter of soil samples was determined by the organic matter oxidation of with dichromic acid of Walky & Black method, (Jackson, 1965). The sodium adsorption ratio (SAR) was calculated as follows (Jackson, 1967):

$$SAR = \text{Soluble Na} / ((\text{soluble Ca} + \text{Mg}) / 2)^{0.5} \text{ (all values as meq/l)}$$

2.3 Statistical analysis

The descriptive statistical analysis of the obtained soil parameters and Factor Analysis (FA) were performed using Statistical Software for Excel (XLSTAT).

3. Results and Discussion

3.1 Physico-chemical properties of soils and yield of growing plants

The statistics of physico-chemical properties of the studied soils cultivated with wheat or sugarcane at Com Ambo, Nasser El-Nubba, and El-Noqra at Aswan governorate are present in Tables (1) and (2). Understanding soil physico-chemical properties such as soil texture, hydraulic conductivity, porosity, soil pH and soil salinity are essential and of importance for managing the use of agricultural resources such as agrochemicals and irrigation water, lowering costs and decreasing environmental consequences (Santos-

Francés *et al.*, 2022). The results show that the soil texture is mainly dominated by sand fraction, which ranged from 42.67 to 93.34% (with an average of 71.30%.) in the soils cultivated with wheat crop, and from 52.61 to 85.17% (with an average of 69.65%) in the sugar cane soils. About 71% of the wheat cultivated soil samples are sandy and 29% are loamy, while 66% of the sugarcane soils are sandy loam, 29 % are loamy and only 5% are sandy clay (Table 1).

Table (1): Statistical parameters for soil physical properties.

Statistical parameters	SP (%)	Clay (%)	Silt (%)	Sand (%)	Hydraulic conductivity (cm/h)	Particle density (Mgm^3)	Bulk density (Mgm^3)	Porosity (%)
Surface samples (0-30 cm) from soils cultivated with wheat								
Min	19.40	2.35	1.33	42.67	0.19	2.43	1.21	32.35
Max	64.80	28.34	41.34	93.34	15.00	2.75	1.65	55.35
Mean	35.85	9.30	19.60	71.30	3.38	2.63	1.36	48.21
±SD	9.71	5.72	10.35	12.55	4.29	0.06	0.09	4.36
Surface samples (0-30 cm) from soils cultivated with sugar cane								
Min	29.20	1.92	6.16	52.61	0.19	2.60	1.13	47.08
Max	58.80	20.85	41.18	85.17	11.95	2.75	1.40	57.96
Mean	43.85	8.40	21.94	69.65	2.65	2.66	1.29	51.73
±SD	8.39	4.72	8.35	8.80	3.39	0.05	0.07	2.91

SP (%): Soil water saturation percentage.

The parent material of the soils of the study area is either Nile valley deposits or the Nubian Sandstone rocks. Going to the East in Aswan governorate the Nubian Sandston dominates. This confirms that the obtained finding that the texture of the soils is mainly dominated by the sand fraction. The hydraulic conductivity (HC) values of the soils cultivated with wheat and sugarcane vary from 0.19 to15.00 cm/h with an average of 3.38 cm/h and from 0.19 to 11.95 cm/h with an average of 2.65 cm/h., respectively. The mean values of particle density, bulk density and porosity, were 2.63 Mg m^{-3}, 1.36 Mg m^{-3} and 48.21% for wheat cultivated soils, and 2.66 Mg m^{-3}, 1.29 Mg m^{-3}, and 51.73% for sugarcane cultivated soils, respectively. The pH values of the wheat cultivated soils range from 7.30 to 8.80, with an average of 8.02, and in sugarcane soils range from 7.14 to 8.18, with an average of 7.70, indicating the basicity/alkalinity of the collected soil samples. The organic matter content (OM) in the soils cultivated with wheat and sugar cane crops, ranged from 0.28 to 3.91% with an average value of 1.81% and from 0.71 to 3.91% with an average of 3.02%, respectively. The higher average of organic matter (OM) of the sugarcane cultivated soils may be due to the location since these soils are mostly the old Nile Valley soils on the river banks, while Wheat cultivated soils extended to the new cultivated land at Wadi El-Noqra to the east from the old Nile Valley. The soil $CaCO_3$ content of the soils cultivated with wheat and sugar cane plants, changes from 0.26 % to 6.87% with an average of 2.53% and from 0.09 % to 5.65% with an average of 2.81%, respectively, suggesting mostly non-calcareous nature. The grain yield of wheat crops varies from 60 to 2850 kg/feddan (feddan = 4200 m² = 0.420 hectares = 1.037 acres), with an average of 2138 kg/feddan, and the raw yield of sugarcane ranges from 20,000 to 52,000 kg/feddan with an average of 37,850 kg/feddan. The 60 kg/feddan was obtained from the worst salinity in the areas.

Table (2): Statistical parameters for soil chemical properties and yield of wheat and sugar cane crops.

Variable	pH (1:2.5)	EC_e (dSm^{-1})	EC $_{1:1}$ (dSm^{-1})	$CaCO_3$ (%)	SOM (%)	Soluble cations (meq/L^{-1})				Soluble anions (meq/L^{-1})			SAR
						Na	K	Ca	Mg	Cl	HCO_3	SO_4	
Surface samples (0-30 cm) from soils cultivated with wheat													
Minimum	7.30	0.72	0.24	0.26	0.28	0.20	0.07	1.30	0.40	1.10	0.90	0.27	0.27
Maximum	8.80	60.0	20.0	6.87	3.91	87.3	6.01	75.1	31.5	142	24.8	82.3	20.7
Mean	8.02	8.90	2.97	2.53	1.81	13.1	1.15	11.7	3.75	13.8	8.96	7.51	5.16
±SD	0.36	12.0	4.00	1.69	1.03	15.7	1.12	19.0	6.09	31.0	5.74	15.1	4.03
Surface samples (0-30 cm) from soils cultivated with sugarcane													
Minimum	7.14	2.52	0.84	0.09	0.71	1.35	0.18	2.50	1.19	2.40	4.58	0.45	0.77
Maximum	8.18	18.35	6.12	5.65	3.91	25.66	6.14	18.50	17.00	15.45	23.14	35.84	13.22
Mean	7.70	7.28	2.43	2.81	3.02	13.25	1.64	6.08	3.29	6.22	13.80	4.13	6.53
±SD	0.29	3.38	1.13	1.44	0.90	6.85	1.82	3.38	3.30	3.84	4.99	7.39	3.47
Yield (kg/feddan)													
Statistical Variable	Wheat grain	Raw sugarcane											
Minimum	60	20,000											
Maximum	2,850	52,000											
Mean	2,138	37,850											
±SD	780	6,953											

3.2 Soil salinity level and mapping

The soils salinity of the studied locations of Aswan soils are presented in the maps in Figure (1A) as $EC_{1:1}$ values and in Figure (1B) as EC_e values. This Figure was drowned using Arc. View 10.8. The results indicate that Aswan soils cultivated with both wheat and sugarcane crops show all salinity classes, varying from non-saline to an extremely saline class (Table 3). The elevation of the study area declines from east downward to the Nile Valley from more than 158 to 84 meter. However, the salinity trend decreases in the same direction, because the newly cultivated soils are located at the east with an old marine sediment of shale's inherited soil salinity. Soil salinity is one of the main environmental factors that adversely affect plant growth and development and it is a major land degradation problem (Metternicht and Zinck, 2003). This problem most prevails in arid and semi-arid regions of the world (Moghaddam and Koocheki, 2004). Soil salinity has resulted in limiting agricultural land-use patterns. Increasing the concentration of salts in the soil is a severe environmental hazard, which causes fertility loss, changes soil physical and chemical characteristics and reduces soil infiltration and water storage which adversely affect the growth of many crops.

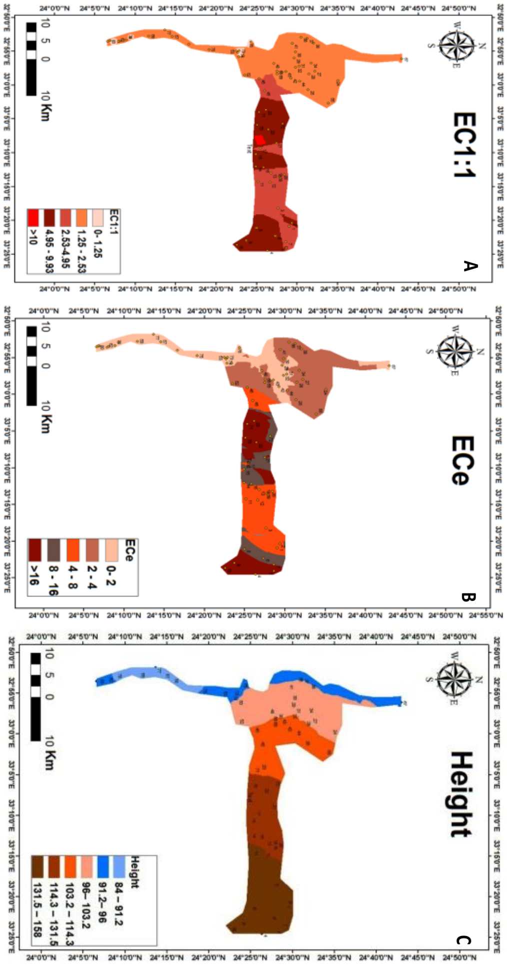

Figure (1): Soil salinity distribution map of Aswan soils as $EC_{1:1}$ (A), and EC_e (B) and elevation of study area of Aswan (C).

Table (3): Soil salinity classes (Smith and Doran, 1996 adapted from Dahnke and Whitney, 1988).

Texture*	Degree of salinity				
	Non-saline	Slightly saline	Saline	Strongly saline	Extremely saline
$EC_{1:1}$					
Coarse to loamy sand	0-1.1	1.2-2.4	2.5-4.4	4.5-8.9	9.0
Loamy fine sand to loam	0-1.2	1.3-2.4	2.5-4.7	4.8-9.4	9.5
Silty loam to clay loam	0-1.3	1.4-2.5	2.6-5.0	5.1-10.0	10.1
Silty clay loam to clay	0-1.4	1.5-2.8	2.9-5.7	5.8-11.4	11.5
Average	0-1.25	1.35-2.53	2.63-4.95	5.05-9.93	10.03
EC_e					
All texture	0-2.0	2.1-4.0	4.1-8.0	8.1-16	16.0

Our results show that the measured values of $EC_{1:1}$ range from 0.24 to 20.0 dSm^{-1} (with an average of 2.97 dS m^{-1}) in wheat soils and from 0.84 to 6.12 dS m^{-1} (with an average of 2.43 dS m^{-1}) in sugarcane cultivated soils (Table 4). Nevertheless, the values of calculated EC_e from $EC_{1:1}$ ranged from 0.72 to 60.0 (with an average of 8.90 dSm^{-1}) in wheat soils and from 2.52 to 18.35 dS m^{-1} (with an average of 7.28 dS m^{-1}) in sugarcane cultivated soils. As it is expected, a wide range in the levels of salinity has been found when comparing $EC_{1:1}$ with EC_e values, because the EC_e values calculated from $EC_{1:1}$ by multiplying a conversion factor of 3 (USDA, 1954). Previously, in literature, it was reported that the values of EC_e, which were measured in the saturated paste, were higher than those of EC1:1, mainly due to dilution effect (USDA, 1954; Zhang *et al*., 2005). The soil cultivated with wheat has 22.93% of non-saline soil and 8.33% of slightly saline ones with a total of 31.22% that have less than 4 dS m^{-1} based on the calculated EC_e. Moreover, the saline, strong and extremely saline sample represent 45.93%, 10.42% and 12.5% of the total wheat cultivated area, respectively. According to the USDA, the soil is considered as saline if salinity exceeds 4 dSm^{-1} and the risks increase with increasing salinity degree. The results indicates that the investigated soil samples with a total of 68.72% have an EC_e value of more than 4 dSm^{-1}. However, using the proposed scale of $EC_{1:1}$ according to the salinity classes associated with soil texture dramatically change to be 29.16% of the investigated soil samples are none-saline (less than 1.25 dSm^{-1}), and 47.9 % are slightly saline (less than 2.53 dSm^{-1}) with a total of 77.06% ranged from non-saline to slightly saline.

Table (4): Contribution percentage (%) of soil samples for salinity based on agronomic classification (United States Salinity Laboratory, USDA, 1954).

Class name	Non-saline	Slightly saline	Saline	Highly saline	Extremely saline
Value dSm^{-1}	EC_e < 2	EC_e = 2-4	EC_e = 4-8	EC_e = 8-16	EC_e >16
Class effect	Not affected	Sensitive crop affected	Many crops affected	Only tolerant crops possible	A few very tolerant crops possible
Samples collected from soils cultivated with wheat plants					
ECe ** (48 Samples)	11	4	22	5	6
(%)	22.9	8.33	45.8	10.42	12.5
$EC_{1:1}$* (48 samples)	14	23	5	1	5
(%)	29.16	47.9	10.4	2.08	10.4
Samples collected from soils cultivated with sugarcane					
EC_e (21 samples)	0.0	4	12	4	1
(%)	0.0	19.05	57.14	19.05	4.67
$EC_{1:1}$* (21 Samples)	4	8	8	1	
(%)	19.04	38.08	38.08	4.76	--

Meanwhile, 10.4%, 2.08% and 10.4 % of the studied soil samples are considered saline, strong saline and extremely saline, respectively with total of 22.88 %. Using the USDA proposed scale is in favour of Aswan soils, but it depends on the field appearance and crop growth. Sugarcane is the major agricultural crop in the part of investigated area, which it shows a typical glycophyte exhibiting stunted growth or no growth at high salinity levels (more than 19 dS/m^{-1}). Soil salinity in the root zone of sugarcane decreases the yield through its effect on biomass. Above a soil salinity threshold of 1.7 dSm^{-1}, the sugarcane yield decreases with increasing salinity (Blackburn, 1984). The results indicate that 19.05% of the tested soil samples of the sugarcane cultivated area are slightly saline class. Meanwhile, 57.14 %, 19.05 % and 4.67 % of esthe soil samples show, saline, strongly saline and the extremely saline classes, respectively. This result indicates that 80.86% of soil samples of the sugarcane soils has an EC_e of > 4 dSm^{-1} (Table 5). While using the proposed scale of $EC_{1:1}$, the percentage soil samples, respectively, increased from 0% to 19.04% for the non-saline class, and from 19.05% to 38.08% for the slightly saline class, but they decreased from 57.14% to 38.08 % for the saline class, from 19.05 to 4.76% for the highly saline class, and from 4.67 % to 0.0 for the extremely saline class.

Table (5): Salinity classes based on the measured $EC_{1:1}$ and the calculated EC_e of the soil samples.

Soil cultivated with wheat plants						Soil cultivated with sugar cane plants					
Sample No.	$EC_{1:1}$ (dS/m)	Soil texture grade	Salinity class	EC_e (dS/m)	Salinity class	Sample No.	$EC_{1:1}$	Soil texture	Salinity class	EC_e (dS/m)	Salinity class
1	2.04	Sandy loam	Slightly saline	6.13	Saline	1	2.63	Sandy clay loam	Saline	7.90	Saline
2	2.14	Sandy loam	Slightly saline	6.42	Saline	2	1.21	Sandy loam	Non-saline	3.63	Slightly saline
3	6.02	Sandy clay loam	Strongly saline	18.05	Extremely	3	1.23	Sandy loam	Non-saline	3.69	Slightly saline
4	11.64	Sandy loam	Extremely saline	34.93	Extremely	4	0.84	Loamy sand	Non-saline	2.52	Slightly saline
5	2.08	Sandy loam	Slightly saline	6.25	Saline	5	1.26	Sandy loam	Non-saline	3.79	Slightly saline
6	1.96	Sandy loam	Slightly saline	5.87	Saline	6	2.10	Loamy sand	Slightly saline	6.31	Saline
7	2.16	Sandy loam	Slightly saline	6.47	Saline	7	2.43	Loamy sand	Saline	7.30	Saline
8	1.70	Loamy sand	Slightly saline	5.11	Saline	8	2.06	Sandy loam	Slightly saline	6.17	Saline
9	11.80	Sandy	Extremely saline	35.4	Extremely	9	2.33	Sandy loam	Slightly saline	6.99	Saline
10	1.93	Sandy loam	Slightly saline	5.78	Saline	10	2.61	Loamy sand	Saline	7.83	Saline
11	2.18	Sandy	Slightly saline	6.53	Saline	11	2.37	Loamy sand	Slightly saline	7.11	Saline
12	2.32	Sandy loam	Slightly saline	6.97	Saline	12	1.88	Sandy loam	Slightly saline	5.64	Saline
13	1.38	Loamy sand	Slightly saline	4.15	Saline	13	3.87	Sandy loam	Saline	11.60	Strongly saline
14	1.75	Loamy sand	Slightly saline	5.26	Saline	14	2.63	Sandy loam	Saline	7.88	Saline
15	1.48	Sandy loam	Slightly saline	4.43	Saline	15	6.12	Sandy loam	Strongly saline	18.35	Extremely
16	2.06	Sandy loam	Slightly saline	6.17	Saline	16	3.69	Sandy loam	Saline	11.08	Strongly
17	1.77	Sand	Slightly saline	5.3	Saline	17	2.20	Sandy loam	Slightly saline	6.60	Saline
18	11.89	Sandy loam	Extremely saline	35.67	Extremely	18	1.62	Sandy loam	Slightly saline	4.87	Saline
19	1.35	Loamy sand	Slightly saline	4.06	Saline	19	1.80	Sandy loam	Slightly saline	5.40	Saline
20	1.14	Sandy	Non-saline	3.41	Slightly	20	3.26	Sandy loam	Saline	9.78	Strongly
21	0.41	Loamy sand	Non-saline	1.24	Non-saline	21	2.80	Loamy sand	saline	8.41	Strongly
22	20.00	Loamy	Extremely saline	60.01	Extremely						
23	14.03	Sandy clay loam	Extremely saline	42.1	Extremely						
24	1.25	Loam	Non-saline	3.74	Slightly						
25	3.41	Sandy loam	Saline	10.22	Strongly saline						
26	2.74	Sandy loam	Saline	8.22	Strongly saline						
27	1.75	Sandy loam	Slightly saline	5.26	Saline						
28	1.29	Sandy loam	Slightly saline	3.87	Slightly						
29	0.45	Loamy sand	Non-saline	1.34	Non-saline						
30	0.39	Sandy loam	Non-saline	1.18	Non-saline						
31	2.05	Loamy sand	Slightly saline	6.16	Saline						
32	2.78	Loamy sand	Saline	8.35	Strongly						
33	0.74	Sandy loam	Non-saline	2.23	Non-saline						
34	0.36	Loamy sand	Non-saline	1.07	Non-saline						
35	2.10	Sandy loam	Slightly saline	6.3	Saline						
36	3.93	Sandy loam	Saline	11.78	Strongly						
37	3.06	Sandy loam	Saline	9.17	Strongly						
38	0.50	Sandy loam	Non-saline	1.5	Non-saline						
39	0.33	Sandy	Non-saline	1	Non-saline						
40	2.46	Sandy loam	Slightly saline	7.39	Saline						
41	0.50	Loamy sand	Non-saline	1.51	Non-saline						
42	1.55	Sandy loam	Slightly saline	4.64	Saline						
43	2.32	Sandy loam	Slightly saline	6.97	Saline						
44	0.37	Loamy sand	Non-saline	1.1	Non-saline						
45	0.49	Loamy	Non-saline	1.48	Non-saline						
46	1.84	Sandy clay loam	Slightly saline	5.51	Saline						
47	0.33	Sandy loam	Non-saline	0.98	Non-saline						
48	0.24	Sandy	Non-saline	0.72	Non-saline						

This indicates that 57.12% of the tested soil samples are at the safe level but 42.84% of the soil samples at the hazardous level. Using the proposed scale based on $EC_{1:1}$ is in favor of Aswan soils. The correlation between $EC_{1:1}$ and EC_e with yield may solve the problem and clarify which is better valid measure.

3.3 Correlations of the soil characteristics and crop yield using multivariate statistical analysis

The correlation study showed significant positive correlations among various parameters of soil samples of the study area (Tables 6 and 7). According to Pearson's coefficient, clay or silt of wheat soils showed a significant negative correlation with hydraulic conductivity with r values of -0.349 and -0.701, respectively. However, clay of wheat soil showed a significant positive correlation with soluble Mg (r= 0.307), soluble Cl (r= 0.312) and SAR (r= 0.325). As it is expected, the texture of investigated samples strongly affects the hydraulic conductivity. The value of HC changes based on the soil texture. It increased with increasing sand fraction and decreases with increasing clay fraction of the investigated soils samples. In this context, according to Pearson's coefficient (r), the content of sand fraction shows a significant positive correlation with hydraulic conductivity (r of 0.731 in the soil cultivated with wheat and 0.752 in the soil cultivated with sugarcane). Several other studies estimated the hydraulic conductivity based on the distribution of soil grain size (Cabalar and Akbulut, 2016; Salarashayeri and Siosemarde, 2012). Additionally, in wheat soils, there is a significant negative relation between porosity, clay, and silt contents with hydraulic conductivity (r of -0.349 and -0.701, respectively). Contrary to texture, the porosity and hydraulic conductivity can change based on number of factors including management, soil moisture, and chemical processes. Soil porosity can be affected by the long-term cultivation, surface crusting and compaction, soil organic matter content, $CaCO_3$ content and salinity. Though the published studies showed a positive relation between porosity and hydraulic conductivity, the values of hydraulic conductivity in the wheat soils of the current study showed a significant negative correlation with porosity (r of -0.415). This indicates that any increase in the soil porosity is not always translated into enhancing in the soil hydraulic conductivity. The pH of the wheat soils exhibited significant negative correlations with EC, soluble Ca, Mg, Na, K, and Cl. Meanwhile, the sugarcane soils pH showed significant negative correlations only with soluble Ca, and Mg. The SAR of the wheat soils has significant positive correlations with EC, soluble Ca, Mg, Na, K, Cl and HCO_3. While that of sugarcane soils SAR showed significant positive correlations with silt, and soluble Na, Cl and HCO_3. In term of crop yield, the wheat grain yield is negatively correlated to the soil bulk density, $EC_{1:1}$, soluble cations (Ca, Mg, Na and K) and soluble anions (Cl and SO_4), SAR, and $CaCO_3$. However, the sugarcane yield is negatively correlated to the bulk density and positively correlated to the porosity. This suggests that these soil parameters might be used and taken into consideration to quantify the quality and productivity of soils cultivated with wheat or sugarcane at Aswan governorate, Egypt.

Table (6): Pearson correlation coefficients (r) of the soil characteristics of wheat cultivated soils.

Variables	Clay (%)	Silt (%)	Sand %	Hydraulic conductivity (cm/h)	Particle density (g/cm^3)	Bulk density (g/cm^3)	Porosity (%)	pH (1:2.5)	EC 1:1 (dS/m)	Na (mmol$_c$/l)	K (mmol$_c$/l)	Ca (mmol$_c$/l)	Mg (mmol$_c$/l)	Cl (mmol$_c$/l)	HCO$_3$ (mmol$_c$/l)	SO$_4$ (mmol$_c$/l)	SAR	CaCO$_3$ (%)	O.M (%)	Grain yield of wheat (kg/feddan)
Clay (%)	1																			
Silt (%)	0.160	1																		
Sand (%)	-0.557	-0.895	1																	
Hydraulic conductivity (cm/h)	-0.349	-0.701	0.731	1																
Particle density (g/cm^3)	0.139	0.195	-0.231	-0.341	1															
Bulk density (g/cm^3)	-0.125	-0.216	0.245	0.372	-0.411	1														
Porosity (%)	0.138	0.248	-0.277	-0.415	0.642	-0.959	1													
pH (1:2.5)	-0.219	-0.249	0.307	0.193	0.263	-0.138	0.175	1												
EC 1:1 (dS/m)	0.267	0.263	-0.335	-0.176	0.060	0.227	-0.172	-0.347	1											
Na(mmol$_c$/l)	0.255	0.288	-0.340	-0.207	0.120	0.222	-0.143	-0.339	0.955	1										
K(mmol$_c$/l)	0.269	0.258	-0.344	-0.200	0.020	0.226	-0.180	-0.325	0.758	0.752	1									
Ca (mmol$_c$/l)	0.229	0.202	-0.277	-0.131	0.012	0.211	-0.179	-0.329	0.961	0.843	0.669	1								
Mg (mmol$_c$/l)	0.307	0.303	-0.379	-0.171	0.036	0.233	-0.179	-0.325	0.965	0.927	0.769	0.898	1							
Cl (mmol$_c$/l)	0.312	0.202	-0.314	-0.103	0.020	0.272	-0.214	-0.352	0.917	0.875	0.793	0.859	0.936	1						
HCO$_3$ (mmol$_c$/l)	0.089	0.187	-0.157	-0.383	0.205	-0.167	0.194	-0.155	0.120	0.266	0.143	0.020	0.017	-0.095	1					
SO4 (mmol$_c$/l)	0.175	0.233	-0.267	-0.137	0.009	0.155	-0.136	-0.215	0.831	0.729	0.457	0.873	0.776	0.590	0.098	1				
SAR	0.325	0.146	-0.245	-0.274	0.196	0.120	-0.031	-0.183	0.486	0.671	0.452	0.302	0.429	0.420	0.625	0.276	1			
CaCO$_3$ (%)	0.161	0.355	-0.362	-0.289	0.172	0.072	-0.006	-0.120	0.428	0.460	0.361	0.364	0.431	0.425	0.297	0.263	0.390	1		
O.M (%)	-0.015	0.267	-0.192	-0.207	0.015	-0.180	0.171	-0.214	-0.276	-0.197	-0.161	-0.325	-0.268	-0.288	0.332	-0.322	-0.018	0.014	1	
Grain yield of wheat (kg/feddan)	-0.245	-0.087	0.173	0.159	0.107	-0.291	0.284	0.446	-0.607	-0.570	-0.430	-0.602	-0.571	-0.539	-0.259	-0.520	-0.403	-0.285	0.082	1

R=0.273 ($p < 0.05$) R= 0.354 ($p < 0.01$) R= 0.435 ($p < 0.001$).

Table (7): Pearson correlation coefficients (r) of the soil characteristics of sugarcane cultivated soils.

Variables	Clay (%)	Silt (%)	Sand %	Hydraulic conductivity (cm/h)	Particle density (g/cm^3)	Bulk density (g/cm^3)	Porosity (%)	pH (1:2.5)	EC 1:1 (dS/m)	Na (mmol$_c$/l)	K (mmol$_c$/l)	Ca (mmol$_c$/l)	Mg (mmol$_c$/l)	Cl (mmol$_c$/l)	HCO$_3$ (mmol$_c$/l)	SO$_4$ (mmol$_c$/l)	SAR	CaCO$_3$ %	O.M (%)	Raw sugar yield (kg/feddan)
Clay (%)	1																			
Silt (%)	-0.185	1																		
Sand (%)	-0.360	-0.850	1																	
Hydraulic conductivity (cm/h)	-0.287	-0.630	0.752	1																
Particle density (g/cm^3)	-0.126	-0.164	0.223	0.372	1															
Bulk density (g/cm^3)	0.181	-0.262	0.152	0.040	-0.259	1														
Porosity (%)	-0.200	0.183	-0.067	0.079	0.525	-0.958	1													
pH (1:2.5)	0.256	-0.245	0.096	0.152	-0.002	-0.232	0.206	1												
EC 1:1 (dS/m)	-0.166	0.147	-0.051	-0.189	0.116	-0.178	0.185	-0.424	1											
Na (mmol$_c$/l)	-0.099	0.408	-0.334	-0.381	0.104	-0.378	0.359	-0.221	0.831	1										
K(mmol$_c$/l)	-0.112	-0.671	0.697	0.703	0.507	-0.036	0.180	0.009	0.174	0.010	1									
Ca (mmol$_c$/l)	-0.101	-0.036	0.089	-0.123	-0.023	0.052	-0.059	-0.526	0.767	0.335	0.040	1								
Mg (mmol$_c$/l)	-0.194	0.057	0.050	-0.110	-0.066	0.141	-0.147	-0.449	0.805	0.414	-0.008	0.870	1							
Cl (mmol$_c$/l)	-0.114	-0.027	0.087	0.107	0.277	-0.285	0.324	-0.114	0.759	0.723	0.424	0.413	0.442	1						
HCO$_3$ (mmol$_c$/l)	-0.040	0.180	-0.150	-0.283	0.263	-0.387	0.419	-0.243	0.449	0.628	0.145	0.134	0.011	0.202	1					
SO4 (mmol$_c$/l)	-0.179	0.116	-0.014	-0.139	-0.135	0.125	-0.155	-0.414	0.801	0.451	-0.043	0.837	0.962	0.488	-0.094	1				
SAR	-0.124	0.507	-0.415	-0.374	0.153	-0.473	0.459	0.095	0.415	0.829	-0.064	-0.188	-0.075	0.484	0.554	0.003	1			
CaCO$_3$ (%)	0.195	0.047	-0.149	-0.065	0.198	-0.016	0.071	0.307	0.132	0.252	0.258	-0.232	0.033	0.227	0.017	0.068	0.331	1		
O.M %	-0.139	-0.304	0.363	0.103	-0.159	-0.068	0.008	-0.259	0.401	0.274	0.232	0.431	0.231	0.306	0.418	0.165	0.008	-0.416	1	
Raw sugar yield (kg/feddan)	-0.344	0.269	-0.071	0.161	0.040	-0.586	0.536	0.090	-0.068	0.002	-0.063	-0.089	-0.112	-0.020	0.051	-0.107	0.115	-0.318	0.099	1

R=0.413 ($p < 0.05$) R= 0.526 ($p < 0.01$) R= 0.639 ($p < 0.001$).

3.4 Multivariate statistical analysis

The multivariate analysis is widely used for assessing soil quality (Nosrati, 2012). Though numerous soil parameters are needed to evaluate soil quality, using principal component analysis is considered one of the most methods to reduce the number of parameters (Firdous *et al*., 2016). Our results showed that the first four components were selected in the factor analysis (FA) applied to wheat soils, mainly due to their eigenvalues > 1 (Figure 1A and Table 8). These principal factor components of wheat soils accounted for ~68% of the total variation. The remaining seven components contributed to the residual ~32% of variation as shown in the scree plot (Figure 1B and Table 8). According to the loading component theory, only factor loadings (correlation values) greater than 0.50 should be considered in explaining the factor components.

Table (8): Eigenvalues and corresponding values of percentage of variance for each component of wheat and sugarcane soils.

Wheat soils											
Variables	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Eigenvalue	7.440	3.450	1.451	1.290	0.528	0.420	0.299	0.085	0.025	0.019	0.011
Variability (%)	37.198	17.251	7.255	6.448	2.641	2.099	1.497	0.427	0.125	0.093	0.056
Cumulative %	37.198	54.449	61.703	68.151	70.792	72.891	74.388	74.815	74.940	75.033	75.089
Sugarcane soils											
Variables	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	
Eigenvalue	5.126	3.774	3.323	1.816	1.246	0.822	0.593	0.267	0.124	0.035	
Variability (%)	25.631	18.868	16.615	9.080	6.232	4.111	2.964	1.335	0.620	0.177	
Cumulative %	25.631	44.498	61.113	70.193	76.426	80.536	83.501	84.835	85.455	85.632	

The positive loadings on the first component (explaining 37.20% of total variation) were large and positive for EC (r^2= 0.988), soluble Ca (r^2= 0.945), soluble Mg (r^2= 0.966), soluble K (r^2= 0.722), soluble Na (0.924), soluble Cl (r^2= 0.919), and SO_4 (r^2= 0.774) and negative loading for grain yield of wheat (r^2= -0.561) (Table 9). This factor is called soil salinity and soluble ions that influence negatively on the grain yield of wheat. The second factor accounts for 17.3% of the variance in the data. This factor is highly correlated positively with porosity (r= 0.97), followed by being moderately corelated with particle density (r= 0.631), and negatively correlated with bulk density (r= -0.797).

Table (9): Factor loading values after varimax rotation for wheat and sugarcane soils.

Wheat soils					Sugarcane soils					
Property	F1	F2	F3	F4	Property	F1	F2	F3	F4	F5
Clay (%)	0.266	0.105	0.103	0.335	Clay (%)	-0.277	-0.123	-0.482	0.196	0.176
Silt (%)	0.162	0.134	0.064	0.836	Silt (%)	0.115	-0.889	0.312	0.088	0.107
Sand (%)	-0.253	-0.161	-0.037	-0.953	Sand (%)	0.056	0.887	-0.002	-0.189	-0.221
Hydraulic conductivity (cm/h)	-0.104	-0.314	-0.271	-0.691	Hydraulic conductivity (cm/h)	-0.052	0.801	0.216	0.041	-0.328
Particle density (g/cm^3)	0.079	0.631	0.161	0.083	Particle density (g/cm^3)	-0.030	0.387	0.341	0.224	0.197
Bulk density (g/cm^3)	0.220	-0.797	-0.014	-0.209	Bulk density (g/cm^3)	0.096	0.077	-0.862	0.016	-0.307
Porosity (%)	-0.145	0.970	0.061	0.186	Porosity %	-0.097	0.068	0.897	0.078	0.327
pH (1:2.5)	-0.262	0.301	-0.154	-0.337	pH (1:2.5)	-0.468	0.119	0.113	0.351	-0.057
EC 1:1 (dS/m)	0.988	-0.056	0.094	0.105	$EC_{1:1}$ (dS/m)	0.817	0.028	0.087	-0.046	0.568
Na(mmolc/l)	0.924	-0.045	0.298	0.106	Na (mmolc/l)	0.436	-0.210	0.207	0.055	0.839
K(mmolc/l)	0.722	-0.123	0.143	0.185	K(mmolc/l)	0.041	0.887	0.090	0.130	0.214
Ca (mmolc/l)	0.945	-0.061	-0.047	0.073	Ca (mmolc/l)	0.863	0.046	-0.083	-0.312	0.073
Mg (mmolc/l)	0.966	-0.076	0.000	0.168	Mg (mmolc/l)	0.961	-0.013	-0.093	-0.018	0.023
Cl (mmolc/l)	0.919	-0.121	-0.039	0.120	Cl (mmolc/l)	0.510	0.261	0.218	0.165	0.525
HCO_3 (mmolc/l)	0.012	0.120	0.923	0.121	HCO_3 (mmolc/l)	-0.019	-0.044	0.192	-0.300	0.730
SO_4 (mmolc/l)	0.774	-0.024	0.000	0.068	SO_4 (mmolc/l)	0.986	-0.076	-0.080	0.077	0.004
SAR	0.439	0.005	0.669	0.070	SAR	-0.027	-0.293	0.347	0.214	0.751
$CaCO_3$ (%)	0.387	0.019	0.272	0.248	$CaCO_3$ (%)	-0.007	0.059	-0.089	0.757	0.304
O.M (%)	-0.364	-0.017	0.281	0.333	O.M (%)	0.219	0.294	-0.028	-0.706	0.323
Grain yield of wheat (kg/feddan)	-0.561	0.272	-0.270	-0.102	Raw sugar yield (kg/feddan)	-0.067	-0.103	0.686	-0.232	-0.157

Wheat; R=0.273 ($p < 0.05$) R= 0.354 ($p < 0.01$) R= 0.435 ($p < 0.001$). Sugarcane; R=0.413 ($p < 0.05$) R= 0.526 ($p < 0.01$) R= 0.639 ($p < 0.001$).

This factor is called soil aeration because it is a function of soil porosity and bulk density. The third factor accounts for 7.26% of the variance in the data. This factor is highly corelated with soluble HCO_3 (r=0.923) and moderately correlated with SAR (r= 0.669), representing bicarbonates and sodium hazard. The fourth factor accounts for 6.448% of the variance in the data. This

PC showed highly positive correlation with silt (r= 0.836) and negative correlation with sand (r=-0.953) and hydraulic conductivity (r=-691). This component is simply referred to as soil texture related to hydraulic conductivity.

In the sugarcane soils, the first five factors were selected (Table 9), mainly due to their eigenvalues > 1 (Table 8). These principal factor components accounted for ~76.43% of the total variation. The remaining five components contributed to the residual ~24% of variation as shown in the scree plot (Figure 2 and Table 8). The positive loadings on the first component (explaining 25.63% of total variation) were large and positive for EC, soluble Ca, soluble Mg, and soluble SO_4 (Table 9), referring to salinity and soluble ions component. The second factor accounts for 18.87% of the variance in the data. This factor showed positive relation with sand, hydraulic conductivity and soluble K and negatively with silt. The third factor accounts for 16.62% of the variance in the data. This factor showed positive relation with pH and sugar cane yield but negative relation with bulk density.

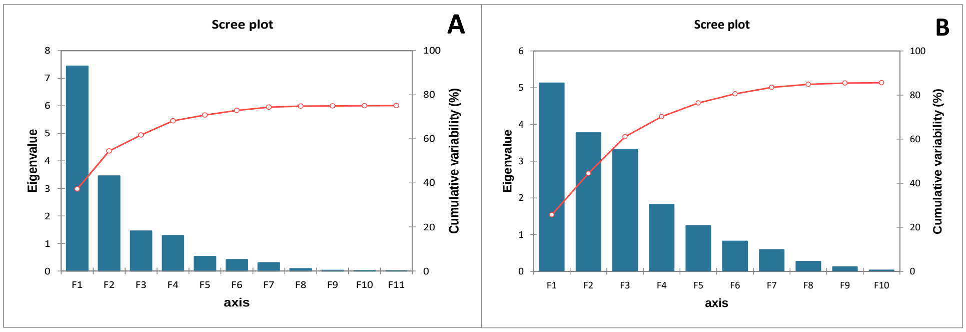

Figure (2): A scree plot showing the relative eigenvalues for the factor components generated for the measured variables of wheat (A) and sugarcane (B) soils.

The fourth factor accounts for 9.08% of the variance in the data. This factor showed positive relation with $CaCO_3$ and negative relation with SOM. Based on the correlation study and multivariate statistical analysis, the yield of wheat grain affected negatively bulk density, EC, soluble cations (Ca, Mg, Na and K) and anions (Cl and SO_4), SAR, and $CaCO_3$. This suggests that the eexcess salts in the root zone of soils in the investigated locations might be responsible for decrease the soil productivity for wheat plants. Soil salinization is considered as a key issue, which impacts the production of irrigated land in arid and semi-arid regions (Saddiq *et al*., 2021; Zewdu *et al*., 2017). It is a serious environmental property that has a negative influence on the growth of a wide range of crop varieties. It has been reported that salt stress can adversely affect wheat productivity by decreasing the rate of germination and growth, and yield through altering enzymatic activity, disrupted photosynthesis, hormonal imbalance, and oxidative stress (Seleiman *et al*., 2022). Salinity adversely affects the growth of plants because of the osmotic stress, sodium toxicity and decreases the nutrients uptake (Salim *et al*., 2020; Zahra *et al*., 2018). However, the sugarcane yield is negatively correlated with bulk density and positively with porosity. High bulk density is an indicator of low soil porosity and soil compaction, reflecting adversely on plant growth (Stirzaker *et al*., 1996). Under such condition, root development may be restricted, and air and water movement through the soil may be compromised. In literature, previous studies showed that the land cultivation with sugarcane can be degraded compared to uncultivated land, mainly due to changes in soil chemical and physical properties under continuous sugarcane production (Qongqo and Antwerpen, 2000). Continuous cultivation has been reported to have a negative influence on the growth and production of sugarcane plants (Pang *et al*., 2021). Therefore, monitoring soil properties under continuous sugarcane cultivation is required to soil management at upper Egypt. Additionally, the obtained results from multivariate analysis and correlation study suggest that land cultivation had strong influence on soil quality parameters those are responsible for soil productivity, depending on the cultivated crop.

4. Conclusion

The measured soil properties suggests that the soils cultivated with wheat or sugarcane at Aswan governorate at Upper Egypt may be suitable for cultivation, with the appeared some salinity problems. Pearson correlation and PCA showed relationships between some of the analysed soil parameters including EC, soluble cations and soluble anions. Additionally, in term of crop yield, the grain yield of wheat is negatively correlated with the bulk density, EC, soluble cations (Ca, Mg, Na and K) and anions (Cl and SO_4), SAR, and $CaCO_3$. However, the sugarcane yield is negatively correlated with bulk density and positively correlated with porosity. This suggests that these soil parameters might be identified as the most representative indicators of agricultural soils at Aswan governorate, Egypt. Based on the obtained results, future studies should focus on monitoring soil physical properties (bulk density and porosity) and soil chemical properties (especially salinity) under continuous crops cultivation for soil management.

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