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Effect of Long-Term Irrigation with Sewage Wastewater on Land Capability of Three Sites in Sohag Governorate, Egypt

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ABSTRACT

The main objective of this study was to evaluate the land capability of three different sites in Sohag Governorate, Egypt where under different periods of irrigation with the sewage waste-water. Nineteen soil profiles were chosen whereas 6, 6 and 7 soil profiles represented Elkoula, Eldair and Elhagarsa sites, respectively. Fifty seven soil samples were collected from the soil profiles (3samples/profile) and then prepared and analyzed for their physico-chemical properties using the standard protocol of analysis. The soils of the three sites were deep, well-drained, coarse textured, neutral, and non-saline. These soils ranged from non-calcareous to calcareous with low content of the soil organic matter and macronutrients. Storie Index was applied for evaluating the land capability in the studied sites. The obtained results revealed that, Elkoula and Elhagarsa soils were under two classes of land capability (G4=poor and G3=fairly good capability) while Eldair soils were under one land capability class (G3=fairly good capability). The mapping of spatial variability distribution of the land capability in the three studied sites was done using the GIS tools. The irrigation of the sewage waste-water affected the land capability of the Elkoula and Elhagarsa sites, while not affected the land capability of the Eldair site. These results and maps can be utilized in the future by the decision makers and stakeholders for better land management of land resources.

Keywords: Capability, Sewage, waste-water, Land evaluation, Storie index, Sohag.

INTRODUCTION

Egypt's critical issue now is the growth of the population in a region where the old agricultural soils are dwindling as a result of urban sprawl and deterioration (Enar *et al*., 2021). The only course of action that can be taken to lessen the effects of this issue is to maximize the advantages of the land resources through optimal utilization. In order to do that, agricultural soils must be thoroughly assessed for both their capacity and appropriateness for all commercial crops. Better land management should be implemented using the findings of the land evaluation to double the advantages of these crucial natural resources. An interpretation of the soil characteristics, crop cover, meteorological conditions, and other data layers related to the particular land-use purpose constitutes a land appraisal. Numerous studies on the evaluation of agricultural land or of capability have been done in Egypt. For instance, Ibrahim *et al*. (2013) examined land capability in the El-Dakhla Oasis, where certain areas had good capability while others only had mediocre capability. Abosafia *et al*. (2022) utilized the ASLE model to assess the capacity of the soils in Kafr El-Sheikh. Their findings showed that the land's capability ranged from very bad to fair. Fayed (2003) assessed the land capability of the El-Bostan region of the West Nile Delta and gave it the capacity levels of moderate and marginal. The primary limiting soil variables in the investigated soils were salinity, calcium carbonate concentration, ESP, and soil texture. When Abd El-Khalek (2004) used the soil capability index to the soils of Wadi El-Rayan and compared the soil characteristics with the Storie index rating, he discovered that half of the analyzed areas were not used for agriculture while the other half had a range of bad to good soils. Abd Al-Hamid *et al.* (2010) evaluated some soils in the Wadi El-Natrun region using the FAO framework, and they found that the study area could be categorized into three categories: moderately suitable (with topography, soil texture, and salinity acting as limiting factors), temporarily unsuitable, and permanently unsuitable. They also calculated the land's potential capabilities, and their results showed that the constraints may be lifted by improving some soil qualities.

Mahmoud *et al.* (2009) determined that the capability of the region ranged between high and moderate capacity classes using the agricultural land evaluation technique to assess the capability of specific Egyptian soils. When Moursy and Thabit (2022) used the Storie index to assess the land capability of various soils in the Sohag Governorate, they discovered that these soils had a wide range of land capability, ranging from bad to excellent. Due to a paucity of water resources, sewage wastewater has been used and used more frequently in recent decades to irrigate landscapes and agriculture (Ganjegunte *et al*., 2018). There is an argument in favour of this usage, and this type of water is viewed as a technological way to improve soil nutrient content and lessen soil degradation (Abd-Elwahed, 2018). Additionally, there are positive effects on the soil properties, such as an increase in organic matter, nitrogen, phosphorus, potassium, and several significant micronutrients (Angin *et al*., 2005). The application of sewage wastewater has a detrimental impact on soil salinity, soil acidity, and soil contamination with heavy metals (Xu *et al*., 2016). Numerous studies have shown that long-term irrigation with wastewater alters the physical and

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chemical qualities of the soil. Additionally, using this type of water degrades the land by causing environmental toxins to build up in the soil. According to Xu *et al.* (2010), while some soil attributes, such as the soil pH, CEC, EC, and compaction, improved, others, such as the soil's capacity to hold nutrients, decreased. According to Abd-Elwahed (2019), using wastewater for irrigation had a detrimental impact on the electrical conductivity (EC), exchangeable sodium percent (ESP), and sodium adsorption ratio (SAR) indicators of soil salinity. Numerous research have been conducted to determine the effects of wastewater application on the physical characteristics of soil. As an illustration, Badaou and Sahin 2022 discussed the benefits of using sewage waste water to irrigate soils, which enhances soil structure as well as soil aeration and infiltration. The porosity, permeability, and saturated hydraulic conductivity of the soil are all impacted by the wastewater. Additionally, the substantial volumes of organic components that the sewage waste water supplies to the soils shield it from potential degradation (Outhman 2016). The period of wastewater application affects how much a specific weight changes (Tabatabaei *et al*., 2020). For instance, long-term irrigation with waste water has an impact on the hydraulic conductivity of saturated soil. According to Banitalebi *et al*. (2016), irrigation of the soil with wastewater for 13 years enhanced the soil's hydraulic conductivity three times more than irrigation with freshwater. Additionally, this study showed that the wastewater had a favourable impact on the soil's bulk density, porosity, and aggregate diameter. The impact of wastewater on the soils in dry and semiarid regions was researched by Lado and Ben-Hur in 2009. In this investigation, the wastewater raised the organic matter content of the topsoil. Similar to this, Shirani *et al*. (2010) showed that wastewater application decreased soil bulk density. According to Mojiri (2011), the pH of the soil dropped after the wastewater was applied. For instance, long-term irrigation with waste water has an impact on the hydraulic conductivity of saturated soil. According to Banitalebi *et al*. (2016), irrigation of the soil with wastewater for 13 years enhanced the soil's hydraulic conductivity three times more than irrigation with freshwater. Additionally, this study showed that the wastewater had a favourable impact on the soil's bulk density, porosity, and aggregate diameter. The impact of wastewater on the soils in dry and semiarid regions was researched by Lado and Ben-Hur in 2009. In this investigation, the wastewater raised the organic matter content of the topsoil. Similar to this, Shirani *et al*. (2010) showed that wastewater application decreased soil bulk density. According to Mojiri (2011), the pH of the soil dropped after the wastewater was applied. Long-term wastewater application may have either a good or detrimental impact on the chemical characteristics of the soil. The impact of sewage water on the chemical characteristics of soil was extensively discussed by researchers. Saffari *et al*. (2008) found a salinity reduction employing the wastewa1.80 to 1.50 dS/m in one of these trials. Shirani *et al*. (2010) discovered, however, that after applying waste water, the soil salinity and SAR increased. The impact of wastewater application on the characteristics of the soil was investigated by Qishlaqi *et al.* in 2008. They discovered a 30% increase in soil organic matter, a drop in soil pH, and an increase in soil CEC. According to Hosseinpour *et al*. (2007), long-term wastewater irrigation reduced the soil organic matter. Similar results were reported in 2016 by (Banitalebi *et al*.). In 2015, Alghobar and Suresha found that sewage wastewater has an impact on the chemical characteristics of various Indian soils. They demonstrated that as compared to untreated soils, the pH, salinity, calcium, magnesium, sulphates, and nitrogen levels were higher. According to Abegunrin *et al*. (2016), the application of wastewater to some Nigerian soils caused an increase in the soil's pH, magnesium, potassium, total organic carbon, total nitrogen, and CEC. Garca-Orenes *et al*. (2015) demonstrated that irrigation with wastewater over a lengthy period of time (up to 45 years) greatly improved soil total organic carbon and accessible phosphorus. Additionally, they noted that soil that has been irrigated with wastewater has a greater EC and a lower pH than untreated soil.

Based on the previous introduction's discussion of the significance of assessing land capability as well as the effects of wastewater application on the physical and chemical properties of soil, this study sought to assess the land capability of three sites in Egypt's Sohag Governorate that were irrigated with sewage wastewater.

MATERIALS AND METHODS

The methodology of this work was concluded in the following flowchart (Figure 1). The methodology included soil and water samples' collection from different studied sites, samples analysis, characterization, land capability evaluation, mapping and recommendations.

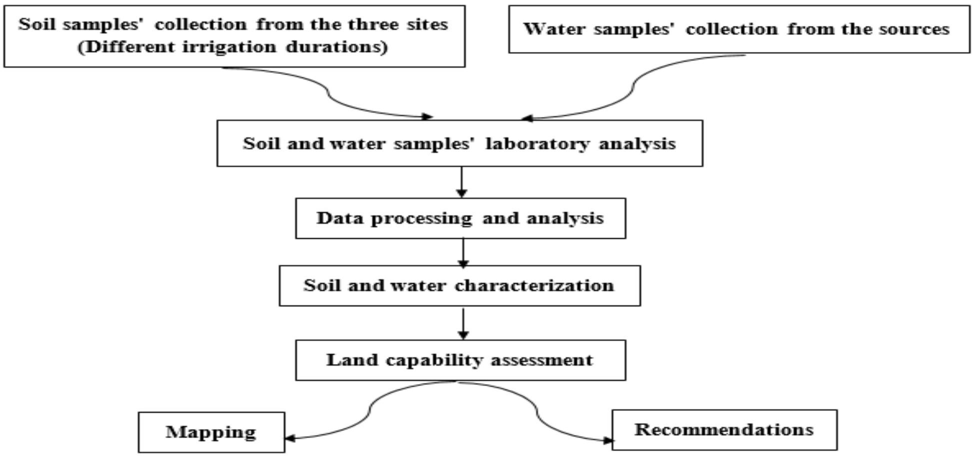

Figure 1. The flowchart of the methodology.

The study sites

Three sites (Elkoula, Eldair, and Elhagarsa) at Sohag Governorate were selected to be studied for their capability where under the long-term irrigation with the sewage water. Location map of the three study sites was represented in the figure (2).

Elkoula site

Elkoula site is located in the eastern part of Sohag where considered the famous site in Sohag Governorate, whose lands are irrigated by sewage water, which is disposed of there. This area is located in the eastern desert hinterland of Sohag Governorate, and these lands are considered newly reclaimed, as they are characterized by their coarse texture, lack of organic matter, macro and microelements, and a moderate content of calcium carbonate. The lands located in Elkoula site have been irrigated with sewage water for a period of more than 20 years. This area is considered a moderately saline and tends to alkalinity. At the El Koula site, forests grow naturally with sewage being dumped there. A variety of trees grow from the camphor (*Cinnamomum camphora*, She-oak (*Casuarina*), moringa (*Moringa*), Nettlespurges (*Jatropha*) and mahogany (*Swietenia mahagoni*).

Eldair site

Eldair site is located west of Sohag where characterized by the average and the lack of organic matter. The soil is slightly saline, inclined to alkaline, with a coarse to medium texture. The macro and micro nutrients fall under the low section, and the same applies to calcium carbonate. The lands located in Eldair site have been irrigated with sewage water for a period of more than 25 years. At Eldair site, jojoba trees (*Simmondsia chinensis*), Nettlespurges (*Jatropha*), Conocarpus (*Conocarpus lancifolius*), and olives (*Olea europaea*) grow.

Elhagarsa site

Elhagarsa site is located in west Sohag near a sewage water station, where most of the area is planted with jojoba trees. This site is characterized by its medium texture and low salinity, the soil is alkaline and has medium calcium carbonate content, and the percentage of organic matter and macro and micro nutrients is low. The lands located in Elhagarsa site are considered to have been recently treated and irrigated with sewage water, as the time for irrigation with that water does not exceed three years. In the third site, Elhagarsa, jojoba trees (Simmondsia chinensis) grow at a rate of more than 95% of the area.

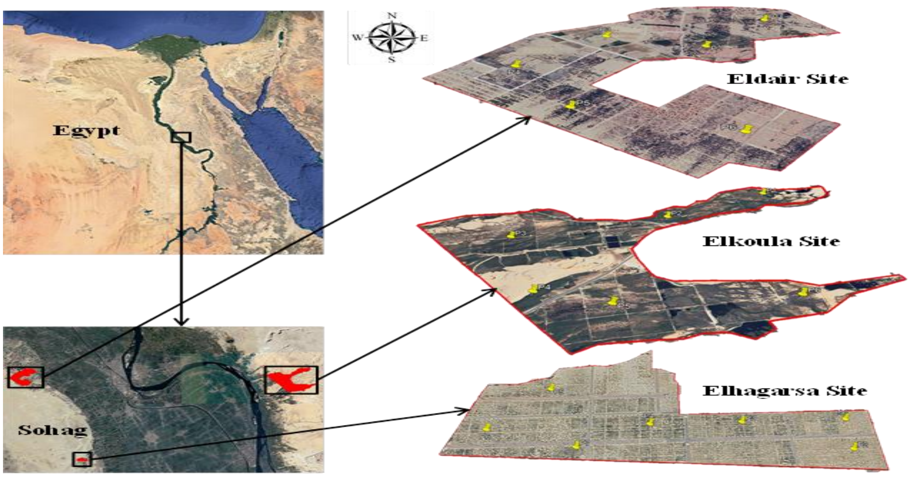

Figure 2. The location map of the studied sites.

The climatic conditions

The three study locations—Elkoula, Eldair, and Elhagarsa—are in the Sohag Governorate, which has a year-round arid climate. The temperature rarely falls below 5°C or rises over 43°C, ranging from 8°C to 39°C. The frequency of rainfall varies seasonally, but not significantly. The greatest wind speed is 10.0 knots, and the average wind speed is around 8.5 knots.

The analysis of sewage waste-water sources

Three water samples were collected from the sewage waste-water sources in the three studied sites (Elkoula, Eldair, and Elhagarsa). The water samples were analyzed using the standard methods of water analysis. The analyzed water quality parameters were pH, total dissolved salts (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), dispersed oil and grease (OG), the dissolved oxygen (DO), the total nitrogen (TN), Hydrogen sulfide (H_2S), Phosphate (PO_4), nitrite and nitrates.

Soil sampling

Based on the time period during which the soil was irrigated by sewage water in the three studied sites, the soil profiles were carefully selected to be representative of each study site. Soil profiles' locations for the three studied sites were demonstrated in figure (3). Six soil profiles were selected from Elkoula site, six soil profiles from Eldair site, and seven soil profiles from Elhagarsa site.

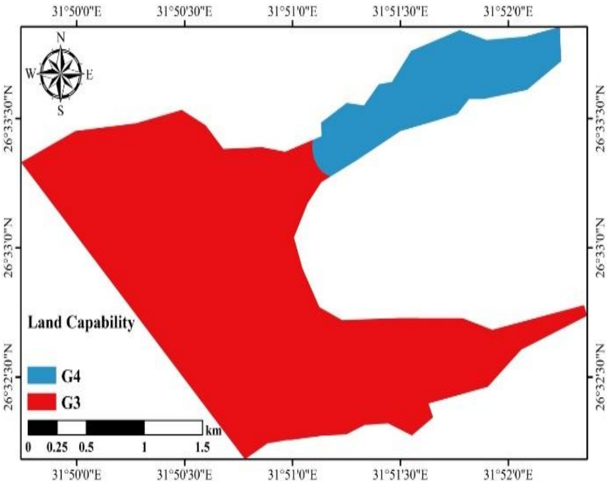

Figure 3. The spatial variability of the land capability in the Elkoula Site.

Soil profiles were selected based on the first site, depending on. The samples were collected from Elkoula site at the same field visit where these six soil profiles were irrigated with the sewage water for periods of zero, 5, 10, 12, 15 and 20 years, respectively. The six soil profiles which represent Eldair site were irrigated with the sewage water for periods of zero, 5, 10, 15, 20 and 25 years, respectively. Elhagarsa site was represented by seven soil profiles irrigated with the sewage water for periods of zero, 0.5, 1, 1.5, 2, 2.5 and 3 years, respectively. Soil samples were collected from each profile, where a sample was from the surface layer of soil from 0 to 30 cm, the second layer from 30 to 60 cm, and the third layer from 60 to more than 100 cm. The GPS "Garmin–eTrix" used to define the geo-coordinates of each soil profile under the WGS84 coordinate system.

Water analysis

The collected water samples were analyzed for their different properties. The water pH was measured directly in the samples using the pH meter. The total dissolved salts (TDS) parameter was calculated from the EC values collected from the EC meter measurements. The chemical oxygen demand (COD), the biological oxygen demand (BOD), the concentration of dispersed oil and grease (OG), and the water content of the Hydrogen sulfide (H_2S), the total nitrogen, the nitrates, the nitrites and the Phosphate (PO_4) content of the water samples were determined using the standard method of water analysis (Rice *et al*., 2012).

Soil analysis

The soil testing laboratory at the Faculty of Agriculture, Sohag University, received the gathered soil samples and moved them there for preparation and analysis. All soil samples were dried in the air for three days, then sieved through a 2 mm sieve after being powdered. In order to determine the physical and chemical properties of soil, soil material (2 mm) was employed as follows: soil particle size distribution was carried out using the pipette method (Jackson, 1969). Electrical conductivity (ECe) was measured in the soil paste extract, calcium carbonate was estimated using the calcimeter method, and soil pH and were assessed in a 1:1 soil-water suspension (Jackson, 1973). Dichromate oxidation was used to measure the organic matter concentration (Walkley and Black, 1934). The micro-kjeldahl method was used to calculate total nitrogen (Jackson, 1973). Available soil Olsen *et al*. (1954) used 0.5M NaHCO3 (pH=8.5) to extract the phosphorus, which was then measured colorimetrically using the chlorostannous phosphomolibdic acid method using a spectrophotometer. available soil Ammonium acetate (pH=7.0) was used to extract potassium (Carson, 1980).

The statistical analysis

Statistics were used to the data that were acquired regarding the examined soil parameters. The weighted mean form was used to show the results for each soil profile across the three study sites. Equation 1 calculates the weighted mean value for each soil attribute (V) in the profile by summing (vi) for each horizon, dividing by horizon thickness (ti), and then dividing by soil profile depth (T).

$$V = \sum_{i=1}^{n} \frac{(vi \times ti)}{T} \qquad \textbf{(Eq. 1)}$$

Each soil parameter at the three study sites underwent a descriptive statistical analysis in which the mean, maximum, minimum, standard deviation, standard error, sample variance, skewness, kurtosis, median, and range were determined.

While the correlation coefficient (r) was calculated for each correlation, the correlation between the soil characteristics was also investigated. The data analysis feature in the MS Excel software was used to perform all calculations and statistical analyses.

Land Capability evaluation

The Storie Index (Storie, 1954) was used to assess the capacity of the soils at the three study sites. It is written as equation (2), based on three different variables: soil profile development (factor 'A'), surface soil texture (factor 'B'), other land factors (factors 'C'), such as slope, drainage, and alkalinity, and factor 'X', which includes other related soil parameters (such as nutrients, salinity, erosion, and micro-relief). Each soil factor was rated in percentage form, multiplied by a decimal, and the resulting index was then reported as a percentage. Storie divided the land's capacity into six grades based on the final index (Table 2).

$$I = A \times B \times C \times X \qquad \textbf{(Eq. 2)}$$

For evaluating the land capability, the land capability index values are rated from 0 to 100 depending on the land capability grades. The grade one (G1) is an Excellent land which has soil rating between 100 and 80 and Suitable for almost all crops. The second grade (G2) is a good land quality (rating is between 60 and 79) whereas the soil is suitable for most crops with good to excellent yields. The fairly good land is the third land capability grade (G3) which has Fair quality, less wide suitability range and give good yields with certain specialized crops and has rating from 40 to 59. The Poor grade (G4) has a rating between 20 and 39 which may give good results for some crops and not-suitable for other crops. The very poor land capability grade (G5) includes the land where has a rating ranged from 10 to 19 and very limited use except for pasture. Non-agricultural land (G6) has lower than 10 soil rating and not-suitable for any economic land use (Storie, 1954).

Mapping of spatial variability

Depending on the spatial data as well as the land capability score of each soil profile in the three studied sites, the spatial variability maps of the land capability status for each studied site were generated using the interpolation method under the geo-statistical analysis tool in the Arc-GIS 10.4 software. All developed maps were classified into five different colored classes to present the land capability variation through each studied site.

RESULTS AND DISCUSSION

The sewage waste-water sources

Table 1 showed the chemical analysis of the sewage waste-water which used for irrigation in the three studied sites (Elkoula, Eldair, and Elhagarsa). The data of water analysis showed that the water pH values of Elkoula, Eldair, and Elhagarsa sites were 7.78, 7.52 and 7.32, respectively. The total dissolved salts (TDS) values of these water were 521, 601, 711 mg/l for the studied sites respectively. Other water quality parameters such as chemical oxygen demand (COD) and biological oxygen demand (BOD) were measured. The COD is commonly used to determine the amount of biologically active substances such as bacteria but also biologically inactive organic matter in water and also used for characterizing water bodies, sewage, industrial wastes, and treatment plant effluents. The BOD test is an important parameter for assessing water quality. It deals with the amount of oxygen consumption by aerobic biological organisms to oxidize organic compounds. Sewage with high BOD can cause a decrease in oxygen of receiving waters, which in turn can cause the death of some organism. However, the COD values for the Elkoula, Eldair, and Elhagarsa were 70, 212, and 233 mg/l, respectively, while the BOD values were 28, 185, and 104 mg/l for the studied sites respectively. The total nitrogen values in the studied water samples were 20, 45, and 44 mg/l, while the values of the oil and grease were 7, 18, and 15 mg/l for Elkoula, Eldair, and Elhagarsa water sources, respectively. The concentration of dispersed oil and grease (OG) is an important parameter for water quality and safety. The OG in water can cause surface films and shoreline deposits leading to environmental degradation, and can induce human health risks when discharged in surface or ground waters. Dissolved oxygen (DO) is a relative measure of the amount of oxygen (O_2) dissolved in water. The oxygen content of water will decrease when there is an increase in nutrients and organic materials from industrial wastewater, sewage discharges, and runoff from the land. However, the dissolved oxygen (DO) and the Hydrogen sulfide (H_2S) values were 4.20-0.80, 0.50-4, and 0.50-3.00 mg/l, for the sites respectively. The Phosphate (PO_4) content of the water samples collected from Elkoula, Eldair, and Elhagarsa was 0.20, 2.50, and 2.00 mg/l, respectively. The nitrites and the nitrates were 8-40, 11-40, and 10-40 mg/l for Elkoula, Eldair, and Elhagarsa, respectively.

Table 1. The characterization of the sewage wastewater in all studied sites.

Water Parameter	Unit	ElKoula	Eldair	Elhagarsa
pH		7.78	7.52	7.32
TDS	mg/l	521	601	711
COD		70	212	233
BOD		28	185	104
TN		20	45	44
OG		7	18	15
DO		4.20	0.50	0.50
H_2S		0.80	4	3
PO_4		0.20	2.50	2
Nitrites		8	11	10
Nitrates		40	40	40

Soil characterization

Soil characterization of Elkoula site

Soil profiles of Elkoula site were well-drained, more than one meter depth, and the slope was about 2 percent. The elevation of the Elkoula site ranged between 84.73 and 112.77 m.a.s.l. Table 2 showed the geo-coordinates of the soil profiles' locations obtained by the GPS, some morphological characters, the weighted mean of soil physico-chemical characteristics of the soil profiles in Elkoula site.

The obtained data showed that Elkoula soils were having coarse texture; whereas sandy, loamy sand and sandy clay loam were the dominant three soil texture classes. Elkoula soils were affected by the sewage waste-water irrigation, whereas soil pH decrease from 7.23 in non-irrigated soils (profile 1) to 6.88 in the long-term irrigated soils (profile 6). Similar increasing trend was recorded for the soil salinity, whereas the soil EC of the non-irrigated soils (profile 1) was 2.73 dS/m while in the long-term irrigated soils (profile 6) was 3.69 dS/m. The site's soils were calcareous whereas the calcium carbonates' content was above 7% in all studied soil profiles, whereas the calcium carbonates content decreased by the time of irrigation with the sewage waste-water. The Elkoula soil profiles showed increase in their content of the soil organic matter by time with the application of the sewage waste-water, whereas non irrigated soils (Profile 1) has the lowest SOM content, while the long-term irrigated soils (profile 6) has the highest SOM content. The total content of the nitrogen increased with the time due to an increase of the soil organic matter content. This was because the effect of the sewage waste-water application on the Elkoula soils with the long-term irrigation. Same trend was recorded for the soil available phosphorus whereas increased with long-term irrigation by the sewage water. However, the soil available potassium's behavior was different, whereas it's content decreased with the sewage water irrigation till twelve years of application (soil profiles 1, 2, 3, and 4) then increased in the rest soil profiles (5 and 6).

These results are matching with the findings of Xu *et al.* (2010); Mojiri (2011); Qishlaqi *et al.* (2008); Hosseinpour *et al.* (2007); Alghobar and Suresha (2015); Abegunrin *et al.* (2016); García-Orenes *et al.* (2015).

Table 2. Soil characterization and the weighted mean (W) of soil physico-chemical properties of the Elkoula soil profiles.

Soil parameter	Soil profiles of Elkoula site					
	P1	P2	P3	P4	P5	P6
Latitudes (N)	26◦.5613	26◦.5562	26◦.5522	26◦.5433	26◦.5416	26◦.5427
Longitudes (E)	31◦.8634	31◦.8532	31◦.8386	31◦.8423	31◦.8486	31◦.8634
Soil profile depth (cm)	100^+	100^+	100^+	100^+	100^+	100^+
Elevation (m.a.s.l)	112.77	102.10	84.73	92.96	90.22	105.15
Slope (%)	2	2	2	2	2	2
Drainage	Well	Well	Well	Well	Well	Well
Sand (%)	87.10	78.95	77.98	72.35	64.53	62.09
Silt (%)	2.30	8.47	8.70	13.92	17.42	16.57
Clay (%)	0.60	2.59	3.32	3.73	8.06	11.35
pH (1:1)	7.23	6.82	6.92	6.96	6.93	6.88
EC_e (dS m^{-1})	2.73	1.91	2.06	2.12	2.74	3.69
SOM (%)	0.08	0.54	0.71	0.78	1.01	1.38
$CaCO_3$ (%)	8.98	8.57	7.85	7.53	7.67	7.93
Total N (%)	0.02	0.12	0.23	0.27	0.39	0.57
Available P (mg Kg^{-1})	4.98	7.68	7.578	7.86	8.256	8.82
Available K (mg Kg^{-1})	136.70	125.65	114.66	110.61	135.36	175.99

The obtained data of the descriptive statistical analysis of the Elkoula soil profiles included mean, standard error, median, standard deviation, sample variance, kurtosis, skewness, range, minimum and maximum were presented in table 3. Regarding the soil textural fractions (Sand, silt, and clay), the mean values were 73.82, 11.23, and 4.94%, respectively. The sand content varied from 62.09 to 87.10%, the silt ranged from 2.30 to 17.42%, while the clay varied between 0.60 to 11.35%. The soil pH of Elkoula site ranged from 6.82 to 7.23 with an average of 6.96. Regarding the soil salinity, the EC mean value was 2.54 dS/m and varied between 1.91 and 3.69 dS/m. The soil organic matter content ranged from 0.08 to 1.38% with a mean value of 0.75%. The minimum and maximum values of the calcium carbonate content were 7.53 and 8.98%, respectively, while the mean value was 8.09%. Regarding the total nitrogen, the mean, maximum, and minimum values were 0.27, 0.05, and 0.57%, respectively. The available phosphorus and the available potassium ranged from 4.98, 110.61 to 8.82, 175.99 mg/kg, respectively, with mean values of 7.53 and 133.16 mg/kg, respectively.

Table 3. The descriptive statistics for the soil physico-chemical properties of the Elkoula soil profiles.

Soil parameter	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Unit		(%)		(1:1)	(dS m^{-1})		(%)			($mg.Kg^{-1}$)
Mean	73.83	11.23	4.94	6.96	2.54	0.75	8.09	0.27	7.53	133.16
Standard Error	3.86	2.37	1.63	0.06	0.27	0.18	0.23	0.08	0.54	9.59
Median	75.17	11.31	3.53	6.93	2.43	0.75	7.89	0.25	7.77	130.51
Standard Deviation	9.44	5.79	3.98	0.14	0.66	0.44	0.56	0.20	1.33	23.49
Sample Variance	89.21	33.57	15.85	0.02	0.44	0.19	0.32	0.04	1.77	551.79
Kurtosis	-1.11	-0.79	-0.19	3.92	0.92	0.69	-0.63	-0.07	3.92	2.36
Skewness	0.04	-0.53	0.92	1.80	1.12	-0.15	0.93	0.47	-1.79	1.40
Range	25.01	15.12	10.75	0.41	1.78	1.30	1.45	0.55	3.84	65.38
Minimum	62.09	2.30	0.60	6.82	1.91	0.08	7.53	0.02	4.98	110.61
Maximum	87.10	17.42	11.35	7.23	3.69	1.38	8.98	0.57	8.82	175.99

The table 4 demonstrated the correlation coefficient values of the soil parameters of Elkoula site. The obtained data revealed that, there was high correlation between the sand parameter and the other soil parameters. The maximum correlation coefficient value was recorded between the sand and the silt (r=-0.98), while the minimum correlation was between the sand and the available potassium (r=-0.50). The silt parameter was in the maximum correlation with the soil organic matter whereas r=0.92, while it was in minimum correlation with the available potassium whereas r=0.32. Regarding the clay parameter, it has maximum and minimum correlation with the total nitrogen (r=0.98) and the soil pH (r=-0.49), respectively. The soil pH was correlated with all soil parameters in a high performance, except with the available potassium and soil EC whereas r=-0.04 and 0.13, respectively. Regarding the soil EC, there was no correlation with the calcium carbonates (r=-0.03) and the available phosphorus (r=0.20). The soil organic matter was in a good correlation with all other soil parameters whereas (r>0.50). The calcium carbonates well negatively correlated with soil total nitrogen (r=-0.69) and available phosphorus (r=-0.77), while was in a poor correlation with the available potassium (r=0.13). The available phosphorus well correlated with the available phosphorus and available potassium. Regarding the available phosphorus, it was not in a good correlation with the available potassium while r=0.25.

Table 4. The correlation between the soil physico-chemical properties of the Elkoula site.

Correlation	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Sand	1.00									
Silt	-0.98	1.00								
Clay	-0.95	0.86	1.00							
pH	0.58	-0.62	-0.49	1.00						
EC	-0.56	0.39	0.75	0.13	1.00					
SOM	-0.97	0.92	0.95	-0.67	0.54	1.00				
$CaCO_3$	0.75	-0.83	-0.56	0.52	-0.03	-0.74	1.00			
Total N	-0.96	0.90	0.98	-0.52	0.67	0.98	-0.69	1.00		
Available P	-0.88	0.90	0.79	-0.88	0.20	0.92	-0.77	0.84	1.00	
Available K	-0.50	0.32	0.73	-0.04	0.94	0.52	0.13	0.61	0.25	1.00

Soil characterization of Eldair site

Soil profiles of Eldair site were well-drained, more than one meter depth, and the slope was about 2 percent. Eldair site's elevation varied from 77.41 to 101.49 m.a.s.l. Table 5 showed the geo-coordinates of the soil profiles' locations obtained by the GPS, some morphological characters, the weighted mean of soil physico-chemical characteristics of the soil profiles in Eldair site.

The obtained data showed that the Eldair soils were having coarse texture; whereas loamy sand, sandy loam and sandy clay loam were the dominant three soil texture classes. Eldair soils were affected by the sewage waste-water irrigation, whereas soil pH slightly decreased from 7.17 in non-irrigated soils (profile 1) to 6.96 in the long-term irrigated soils (profile 6). Slight changes were recorded for Eldair soil salinity, whereas the soil EC in all studied soil profiles was below 2.00 dS/m. The site's soils were not calcareous whereas the calcium carbonates' content was below 5% in all studied soil profiles except (soil profile 1) which has 5.44%. However, the calcium carbonates content decreased by the time of irrigation with the sewage waste-water. The Eldair soil profiles showed a wide range of increase in their content of the soil organic matter by time with the application of the sewage waste-water, whereas non irrigated soils (Profile 1) has the lowest SOM content (0.11%), while the long-term irrigated soils (profile 6) has the highest SOM content (2.16%). The total content of the nitrogen increased with the time due to an increase of the soil organic matter content. This was because the effect of the sewage waste-water application on the Elkoula soils with the long-term irrigation. Same trend was recorded for the soil available phosphorus whereas increased with long-term irrigation by the sewage water.

However, the soil available potassium's behavior was different, whereas its content decreased with the sewage water irrigation in all studied soil profiles except (profile 2) which has the lowest content of the available potassium.

These results are matching with the findings of Xu *et al.* (2010); Mojiri (2011); Qishlaqi *et al.* (2008); Hosseinpour *et al.* (2007); Alghobar and Suresha (2015); Abegunrin *et al.* (2016); García-Orenes *et al.* (2015).

The obtained data of the descriptive statistical analysis of the Eldair soil profiles included mean, standard error, median, standard deviation, sample variance, kurtosis, skewness, range, minimum and maximum were presented in table 6. Regarding the soil textural fractions (Sand, silt, and clay), the mean values were 73.14, 12.24, and 4.61%, respectively. The sand content varied from 65.98 to 79.25%, the silt ranged from 10.06 to 17.56%, while the clay varied between 0.69 to 9.72%. The soil pH of Eldair site ranged from 6.83 to 7.17 with an average of 6.97. Regarding the soil salinity, the EC mean value was 1.73 dS/m and varied between 1.07 and 1.97 dS/m. The soil organic matter content ranged from 0.11 to 2.16% with a mean value of 1.34%. The minimum and maximum values of the calcium carbonate content were 1.86 and 5.44%, respectively, while the mean value was 2.75%. Regarding the total nitrogen, the mean, maximum, and minimum values were 0.40, 0.01, and 0.54%, respectively. The available phosphorus and the available potassium ranged from 5.29, 25.31 to 10.80, 84.80 mg/kg, respectively, with mean values of 8.91 and 59.26 mg/kg, respectively.

The table 7 demonstrated the correlation coefficient values of the soil parameters of Eldair site. The obtained data revealed that, there was high correlation between the sand parameter and the other soil parameters, except with soil pH (r=0.49) and the available potassium (r=0.08). The silt was in the maximum correlation with the soil organic matter whereas r=0.73, while it was not well correlated with the clay (r=0.47), the soil pH (r=-0.30), the soil EC (r=0.40), and the available potassium (r=0.00). Regarding the clay parameter, a reasonable correlation was recorded for all soil parameters except soil EC (r=0.30) and the available potassium (r=-0.12).

The soil pH was correlated with all soil parameters in a high performance, except with the soil EC and available potassium whereas r=-0.07 and -0.12, respectively. Regarding the soil EC, there was no correlation with the all soil parameters except with the available potassium (r=0.87). The soil organic matter was in a good correlation with all other soil parameters except with the available potassium (r=-0.26). The calcium carbonates well negatively correlated with soil total nitrogen (r=-0.98) and available phosphorus (r=-0.94), while was in a poor correlation with the available potassium (r=0.34). The available phosphorus well correlated with the available phosphorus while a poor correlation coefficient value (r=-0.14) was recorded with the available potassium. Regarding the available phosphorus, it was not in a good correlation with the available potassium while r=-0.49.

Table 5. Soil characterization and the weighted mean (W) of soil physico-chemical properties of the Eldair soil profiles.

Soil parameter	Soil profiles of Eldair site					
	P1	**P2**	**P3**	**P4**	**P5**	**P6**
Latitudes (N)	26◦.5603	26◦.5562	26◦.5575	26◦.5534	26◦.5490	26◦.5468
Longitudes (E)	31◦.6128	31◦.6090	31◦.6032	31◦.5987	31◦.6023	31◦.6104
Soil profile depth (cm)	100^+	100^+	100^+	100^+	100^+	100^+
Elevation (m.a.s.l)	77.41	81.68	95.40	101.49	101.19	94.48
Slope (%)	2	2	2	2	2	2
Drainage	Well	Well	Well	Well	Well	Well
Sand (%)	79.25	77.09	74.80	73.70	68.04	65.98
Silt (%)	10.06	10.33	12.35	10.93	12.23	17.56
Clay (%)	0.69	2.58	2.85	5.38	9.72	6.46
pH (1:1)	7.17	7.06	6.83	6.86	6.92	6.96
EC_e (dS m^{-1})	1.97	1.07	1.71	1.80	1.87	1.96
SOM (%)	0.11	0.96	1.32	1.57	1.89	2.16
$CaCO_3$ (%)	5.44	3.24	2.03	2.00	1.92	1.86
Total N (mg Kg^{-1})	0.01	0.23	0.54	0.54	0.54	0.54
Available P (mg Kg^{-1})	5.28	8.88	8.82	9.48	10.2	10.8
Available K (mg Kg^{-1})	84.80	25.31	65.38	62.10	60.05	57.89

Table 6. The descriptive statistics for the soil physico-chemical properties of the Eldair soil profiles.

Soil parameter	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Unit	(%)			(1:1)	(dS m^{-1})	(%)			(mg.Kg^{-1})	
Mean	73.14	12.24	4.61	6.97	1.73	1.34	2.75	0.40	8.91	59.26
Standard Error	2.11	1.13	1.33	0.05	0.14	0.30	0.58	0.09	0.79	7.86
Median	74.25	11.58	4.12	6.94	1.84	1.45	2.02	0.54	9.18	61.08
Standard Deviation	5.16	2.77	3.25	0.13	0.34	0.73	1.42	0.23	1.94	19.25
Sample Variance	26.66	7.69	10.54	0.02	0.11	0.54	2.01	0.05	3.75	370.58
Kurtosis	-1.37	3.68	-0.23	-0.39	4.28	0.62	3.17	0.38	3.17	2.70
Skewness	-0.45	1.84	0.58	0.76	-2.01	-0.87	1.85	-1.35	-1.60	-0.93
Range	13.27	7.50	9.03	0.34	0.90	2.05	3.58	0.53	5.52	59.49
Minimum	65.98	10.06	0.69	6.83	1.07	0.11	1.86	0.01	5.28	25.31
Maximum	79.25	17.56	9.72	7.17	1.97	2.16	5.44	0.54	10.80	84.80

Table 7. The correlation between the soil physico-chemical properties of the Eldair site.

Correlation	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Sand	1.00									
Silt	-0.83	1.00								
Clay	-0.88	0.47	1.00							
pH	0.49	-0.30	-0.52	1.00						
EC	-0.40	0.40	0.30	-0.12	1.00					
SOM	-0.93	0.73	0.85	-0.72	0.19	1.00				
$CaCO_3$	0.75	-0.54	-0.73	0.90	-0.02	-0.93	1.00			
Total N	-0.76	0.55	0.73	-0.94	0.20	0.92	-0.98	1.00		
Available P	-0.85	0.64	0.79	-0.69	-0.06	0.97	-0.94	0.88	1.00	
Available K	0.08	0.00	-0.12	0.07	0.87	-0.26	0.34	-0.14	-0.49	1.00

Soil characterization of Elhagarsa site

Soil profiles of Elhagarsa site were well-drained, more than one meter depth, and the slope was about 2 percent. The elevation of Elhagarsa site ranged from 76.20 to 91.13 m.a.s.l. Table 8 showed the geo-coordinates of the soil profiles' locations obtained by the GPS, some morphological characters, the weighted mean of soil physico-chemical characteristics of the soil profiles in Elhagarsa site.

The obtained data showed that the Elhagarsa soils were having coarse texture; whereas sand, loamy sand, and sandy loam were the dominant three soil texture classes. Elhagarsa soils were affected by the sewage waste-water irrigation, whereas soil pH slightly decreased from 6.98 in non-irrigated soils (profile 1) to 6.81 in the long-term irrigated soils (profile 7). Slight changes were recorded for Elhagarsa soil salinity with the time of the sewage waste-water irrigation. The soil profiles (3, 4, 5, 6, and 7) were not calcareous whereas the calcium carbonates' content was below 5%, while soil profiles (1 and 2) were calcareous (calcium carbonates' content was above 5%). However, the calcium carbonates content decreased by the time of irrigation with the sewage waste-water. The Elhagarsa soil profiles showed a slight increase in their content of the soil organic matter by time with the application of the sewage waste-water, whereas non irrigated soils (Profile 1) has the lowest SOM content (0.05%), while the long-term irrigated soils (profile 7) has the highest SOM content (0.45%). The total content of the nitrogen increased with the time due to an increase of the soil organic matter content. This was because the effect of the sewage waste-water application on the Elhagarsa soils with the long-term irrigation. Same trend was recorded for the soil available phosphorus whereas increased with long-term irrigation by the sewage water except the status of the soil profiles (6 and 7) while a decrease behavior in the available phosphorus was recorded. The highest value of the soil available potassium was represented in the soil profile 1 (non-irrigated with the sewage waste-water), while the trend of the available potassium behavior changed increased or decreased from a soil profile to another in Elhgarsa site.

These results are matching with the findings of Xu *et al.* (2010); Mojiri (2011); Qishlaqi *et al.* (2008); Hosseinpour *et al.* (2007); Alghobar and Suresha (2015); Abegunrin *et al.* (2016); García-Orenes *et al.* (2015).

Table 8. Soil characterization and the weighted mean (W) of soil physico-chemical properties of the Elhagarsa soil profiles.

Soil parameter	Soil profiles of Elhagarsa site						
	P1	P2	P3	P4	P5	P6	P7
Latitudes (N)	26°.4728	26°.4722	26°.4727	26°.4727	26°.4735	26°.4725	26°.4721
Longitudes (E)	31°.6724	31°.6724	31°.6704	31°.6687	31°.6667	31°.6657	31°.6674
Soil profile depth (cm)	100^+	100^+	100^+	100^+	100^+	100^+	100^+
Elevation (m.a.s.l)	76.20	76.40	80.16	84.73	89.61	91.13	86.25
Slope (%)	2	2	2	2	2	2	2
Drainage	Well	Well	Well	Well	Well	Well	Well
Sand (%)	87.80	88.34	85.49	83.83	78.40	74.95	71.37
Silt (%)	1.75	1.53	4.06	4.78	8.07	11.56	12.35
Clay (%)	0.45	0.13	0.45	1.39	3.53	3.49	6.28
pH (1:1)	6.98	6.93	6.88	6.86	6.84	6.85	6.81
EC_e (dS m^{-1})	2.17	2.17	2.13	2.35	2.53	2.41	2.30
SOM (%)	0.05	0.08	0.11	0.18	0.24	0.35	0.45
$CaCO_3$ (%)	5.23	5.12	4.97	4.34	3.77	3.65	3.55
Total N (%)	0.01	0.03	0.05	0.09	0.12	0.20	0.24
Available P (mg Kg^{-1})	5.58	6.27	6.90	7.98	8.82	8.31	7.68
Available K (mg Kg^{-1})	73.76	65.55	56.44	60.61	63.71	62.44	60.72

The obtained data of the descriptive statistical analysis of the Elhagarsa soil profiles included mean, standard error, median, standard deviation, sample variance, kurtosis, skewness, range, minimum and maximum were presented in table 9. Regarding the soil textural fractions (Sand, silt, and clay), the mean values were 81.46, 6.30, and 2.25%, respectively. The sand content varied from 71.37 to 88.34%, the silt ranged from 1.53 to 12.35%, while the clay varied between 0.13 to 6.28%. The soil pH of Eldair site ranged from 6.81 to 6.98 with an average of 6.88. Regarding the soil salinity, the EC mean value was 2.29 dS/m and varied between 2.13 and 2.53 dS/m. The soil organic matter content ranged from 0.05 to 0.45% with a mean value of 0.21%. The minimum and maximum values of the calcium carbonate content were 3.55 and 5.23%, respectively, while the mean value was 4.37%. Regarding the total nitrogen, the mean, maximum, and minimum values were 0.11, 0.01, and 0.24%, respectively. The available phosphorus and the available potassium ranged from 5.58, 56.44 to 8.82, 73.76 mg/kg, respectively, with mean values of 7.36 and 63.32 mg/kg, respectively.

Table 9. The descriptive statistics for the soil physico-chemical properties of the Elhagarsa soil profiles.

Soil parameter	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Unit	(%)			(1:1)	(dS m^{-1})	(%)			(mg.Kg^{-1})	
Mean	81.46	6.30	2.25	6.88	2.29	0.21	4.37	0.11	7.36	63.32
Standard Error	2.50	1.68	0.86	0.02	0.06	0.06	0.28	0.03	0.44	2.05
Median	83.83	4.78	1.39	6.86	2.30	0.18	4.34	0.09	7.68	62.44
Standard Deviation	6.62	4.44	2.28	0.06	0.15	0.15	0.73	0.09	1.16	5.42
Sample Variance	43.84	19.71	5.19	0.00	0.02	0.02	0.53	0.01	1.35	29.38
Kurtosis	-1.42	-1.68	0.00	-0.16	-1.02	-0.82	-2.41	-0.97	-1.02	2.30
Skewness	-0.54	0.41	0.95	0.76	0.45	0.69	0.05	0.66	-0.43	1.15
Range	16.97	10.82	6.15	0.17	0.40	0.41	1.67	0.23	3.24	17.32
Minimum	71.37	1.53	0.13	6.81	2.13	0.05	3.55	0.01	5.58	56.44
Maximum	88.34	12.35	6.28	6.98	2.53	0.45	5.23	0.24	8.82	73.76

The table 10 demonstrated the correlation coefficient values of the soil parameters of Elhagarsa site. The obtained data revealed that, there was either positive or negative correlation among all soil parameters, except with the available potassium whereas low correlation coefficient values were recorded.

Table 10. The correlation between the soil physico-chemical properties of the Elhagarsa site.

Correlation	Sand	Silt	Clay	pH	EC	SOM	$CaCO_3$	Total N	Available P	Available K
Sand	1.00									
Silt	-0.99	1.00								
Clay	-0.97	0.94	1.00							
pH	0.87	-0.88	-0.83	1.00						
EC	-0.63	0.64	0.60	-0.64	1.00					
SOM	-0.99	0.98	0.96	-0.88	0.58	1.00				
$CaCO_3$	0.95	-0.95	-0.92	0.90	-0.82	-0.94	1.00			
Total N	-0.99	0.98	0.95	-0.88	0.58	1.00	-0.94	1.00		
Available P	-0.72	0.74	0.64	-0.87	0.90	0.69	-0.88	0.69	1.00	
Available K	0.36	-0.40	-0.27	0.22	-0.12	-0.40	0.38	-0.40	-0.25	1.00

Land capability evaluation using Storie Index

Elkoula site

The obtained results of land capability evaluation using the Storie index in Elkoula site were shown in Table 11.

Table 11. Land capability evaluation using the Storie index for Elkoula site.

Soil parameter	Factor	P1	P2	P3	P4	P5	P6
Soil profile development	A	100	100	100	100	100	100
Texture	B	60	80	95	95	95	95
Slope (%)		95	95	95	95	95	95
Drainage		100	100	100	100	100	100
Nutrients status		80	80	80	80	80	80
Alkali status	C and X	95	95	95	95	95	95
pH-level		85	85	85	85	85	85
Erosion		100	100	100	100	100	100
Micro-relief		100	100	100	100	100	100
Storie Index score (%)		36.82	49.10	58.30	58.30	58.30	58.30
Land capability Grade		G4tnp	G3tnp	G3np	G3np	G3np	G3np

G3: fair capability class; G4: poor; t: soil texture; n: nutrients; p: pH-level.

The soils of the Elkoula site were categorized into two grades G3 and G4. The soils of profile (1) were under grade 4 (G4tnp) whereas the capability index value was 36.82%. These soils have a relatively narrow range in their agricultural possibilities, in the sense that they may give good results for some crops but be unsuitable for other crops. The major limitations in these soils are the coarsed texture ‘t’, the low nutrients ‘n’ and alkalinity ‘p’. Soil profiles (2, 3, 4, 5, and 6) were under grade 3 (G3np) with a value of the capability score was 49.10% for the soil profile (2), and 58.30% for the soil profiles (3, 4, 5, and 6), respectively. These soils are fairly good quality land with few limitations (low nutrient content ‘n’ and alkalinity ‘p’). The effect of sewage wastewater long-term irrigation on land capability of Elkoula site was obvious by the time. The soil profile (1) which was not irrigated by sewage wastewater has the lowest value of the capability index, while the other soil profiles (2, 3, 4, 5, and 6) which irrigated by sewage wastewater for (5, 10, 12, 15, and 20 years, respectively) have higher capability index value compared to the soils which not irrigated by sewage wastewater.

Eldair site

The obtained results of land capability evaluation using the Storie index in Eldair site were shown in Table 12. The soils of the Eldair site were categorized into one grade (G3). The soils of all studied profiles were under grade 3 (G3np) whereas the capability index value was 49.10% for soil profiles (1 and 2), and 58.30% for soil profiles (3, 4, 5, and 6), respectively. These soils are fairly good quality land with few limitations (low nutrient content ‘n’ and alkalinity ‘p’).

There was no effect of sewage wastewater long-term irrigation on land capability of Eldair site. The soil profiles (1 and 2) which were not irrigated and irrigated by sewage wastewater for 5 years, respectively have the lowest value of the capability index, while the other soil profiles (3, 4, 5, and 6) which irrigated by sewage wastewater for (10, 15, 20 and 25 years, respectively) have higher capability index value.

Table 12. Land capability evaluation using the Storie index for Eldair site.

Soil parameter	Factor	P1	P2	P3	P4	P5	P6
Soil profile development	A	100	100	100	100	100	100
Texture	B	80	80	95	95	95	95
Slope (%)		95	95	95	95	95	95
Drainage		100	100	100	100	100	100
Nutrients status		80	80	80	80	80	80
Alkali status	C and X	95	95	95	95	95	95
pH-level		85	85	85	85	85	85
Erosion		100	100	100	100	100	100
Micro-relief		100	100	100	100	100	100
Storie Index score (%)		49.10	49.10	58.30	58.30	58.30	58.30
Land capability Grade		G3np	G3np	G3np	G3np	G3np	G3np

G3: fair capability class; n: nutrients; p: pH-level.

Elhagarsa site

The obtained results of land capability evaluation using the Storie index in Elhagarsa site were shown in Table 13. The soils of the Elhagarsa site were categorized into two grades G3 and G4. The soils of profiles (1, 2, 3, and 4) were under grade 4 (G4tnp) whereas the capability index value was 36.82%. These soils have a relatively narrow range in their agricultural possibilities, in the sense that they may give good results for some crops but be unsuitable for other crops. The major limitations in these soils are the coarsed texture 't', the low nutrients 'n' and alkalinity 'p'. Soil profiles (5, 6, and 7) were under grade 3 (G3np) with a value of the capability score was 58.30%.

These soils are fairly good quality land with few limitations (low nutrient content 'n' and alkalinity 'p').

The effect of sewage wastewater long-term irrigation on land capability of Elhagarsa site was moderate by the time. The soil profile (1, 2, 3, and 4) which was not irrigated, irrigated by sewage wastewater for 0.5, 1, and 1.5 years, respectively have the lowest value of the capability index, while the other soil profiles (5, 6, and 7) which irrigated by sewage wastewater for (2, 2.5 and 3 years, respectively) have higher capability index value.

From the previous discussion, it can be pointed out that the long-term irrigation with the sewage wastewater affects the land capability by the time. It is because the frequently addition of the organic matter which include macro and micronutrients. The sewage wastewater enhances the soil texture by the time which aggregates the soil granules and improves the soil structure.

Table 13. Land capability evaluation using the Storie index for Elhagarsa site.

Soil parameter	Factor	P1	P2	P3	P4	P5	P6	P7
Soil profile development	A	100	100	100	100	100	100	100
Texture	B	60	60	60	60	95	95	95
Slope (%)		95	95	95	95	95	95	95
Drainage		100	100	100	100	100	100	100
Nutrients status	C	80	80	80	80	80	80	80
Alkali status	and	95	95	95	95	95	95	95
pH-level	X	85	85	85	85	85	85	85
Erosion		100	100	100	100	100	100	100
Micro-relief		100	100	100	100	100	100	100
Storie Index score (%)		36.82	36.82	36.82	36.82	58.30	58.30	58.30
Land capability Grade		G4tnp	G4tnp	G4tnp	G4tnp	G3np	G3np	G3np

G3: fair capability class; G4: poor; t: soil texture; n: nutrients; p: pH-level.

Mapping of the spatial variability of the land capability in the studied sites

The thematic maps of the spatial distribution of the land capability in the three studied sites (Elkoula, Eldair, and Elhagarsa) were demonstrated in the figures (3, 4, and 5), respectively. Each map was demonstrated in one or two different colors depended on the number of land capability classes which obtained from the application of the Storie Index for evaluation. In Elkoula site, the area could be classified to be under two different land capability classes and shown in blue color (G4 = poor capability), and red color (G3 = fairly good capability). Regarding Eldair site, it was evaluated for the land capability and was under one class (G3 = fairly good capability) and presented in one color (red). In Elhagarsa site, the land capability was under two different classes (G4 = poor capability and G3 = fairly good capability), and demonstrated in two different colors (Blue and Red) for capability classes (G4 and G3), respectively.

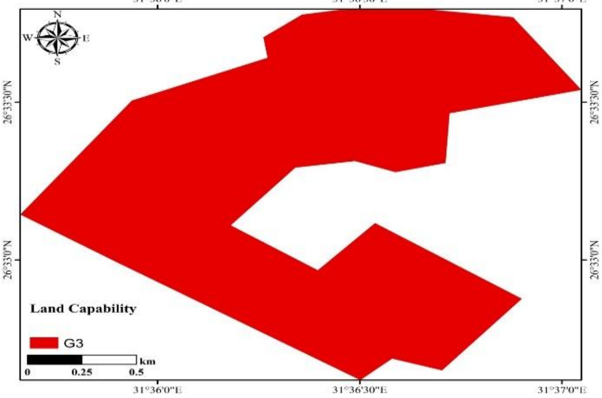

Figure 4. The spatial variability of the land capability in the Eldair Site.

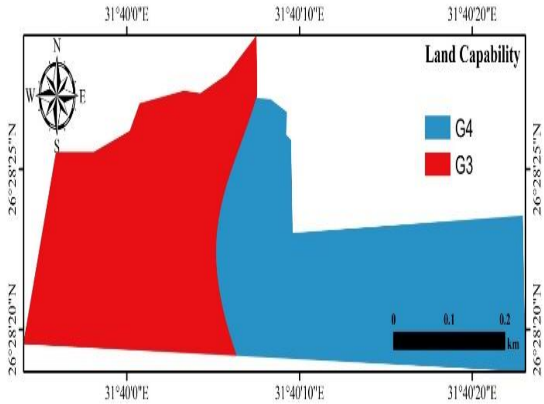

Figure 5. The spatial variability of the land capability in the Elhagarsa Site.

CONCLUSION

The land capability of the three studied sites (Elkoula, Eldair, and Elhagarsa) were evaluated using the Storie Index whereas Elkoula and Elhagarsa were found to be under two capability classes (G4=poor, and G3=fairly good), while Eldair soils were fairly good in their land capability. The obtained results and maps can be utilized in the future by the decision makers and stakeholders for better land management of land resources.

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تأثير الري طويل المدى بمياه الصرف الصحي على قدرة الأرض لثلاثة مواقع في محافظة سوهاج ، مصر

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الملخص

الهدف الرئيسي من هذه الدراسة هو تقييم قدرة الأرض لثلاثة مواقع مختلفة في محافظة سوهاج ، مصر تحت فترات مختلفة من الري بمياه الصرف الصحي. تم اختيار تسعة عشر قطاعا للتربة تمثلت في 6 و 6 و 7 قطاعات تربة من ثلاثة مواقع هي الكولة والدير والهجارسة على التوالي. جمعت سبعة وخمسون عينة تربة من قطاعات التربة (3 عينات / قطاع) ثم تم تجهيزها وتحليل خصائصها الفيزيائية والكيميائية باستخدام الطرق القياسية للتحليل. كانت ترب المواقع الثلاثة عميقة وجيدة التصريف وخشنة البنية وقريبة من التعادل وغير ملحية. وتراوحت هذه الترب بين غير الجيرية إلى الجيرية ذات المحتوى المنخفض من المواد العضوية والمغذيات الكبرى في التربة. تم تطبيق مؤشر ستورى لتقييم قدرة الأرض في المواقع المدروسة. أظهرت النتائج المتحصل عليها أن تربة الكولة والهجارسة كانت تحت فئتين من قدرة الأرض G4 أي ضعيفة و G3 أي جيدة إلى حد ما، بينما كانت تربة الدير تحت فئة قدرة أرضية واحدة G3 أي قدرة جيدة إلى حد ما. تم رسم خرائط توزيع التباين المكاني لقدرة الأرض في المواقع الثلاثة المدروسة باستخدام أدوات نظم المعلومات الجغرافية. أثر ري مياه الصرف الصحي على قدرة الأراضي في موقعي الكولة والهجارسة، بينما لم يؤثر على قدرة الأرض في موقع الدير. يمكن استخدام هذه النتائج والخرائط في المستقبل من قبل صانعي القرار لتحسين إدارة الموارد الأراضية.

الكلمات الدالة: القدرة الانتاجية، مياه الصرف الصحي، تقييم الأراضي، مؤشر ستورى، سوهاج.