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Evaluation of Land Capability and Suitability of Newly Reclaimed Areas in Western Minya, Egypt

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THE AIM of this study was to evaluate land capability and suitability indices of soils in western of El-Minya Governorate, Egypt. El-Minya is considered as one of the most important locations for land reclamation in the western desert, located at 27º 52′ 00"; 27º 55′ 00″ N and 29º 55′ 00″; 30º 1′ 00″ E, covering a total area of 36.76 km^2 in the western Nile River region. Fifty soil profiles were dug to represent the geomorphological units in the studied area. Five geomorphological units were established; i) *Deep sandy, mixed, hyperthermic, Typic Haplocalcids* ii) *Shallow sandy skeletal, mixed, hyperthermic, Typic Haplocalcids* iii) *Sandy skeletal, mixed, hyperthermic, Typic Calcigypsids* iv) *Sandy skeletal, mixed, hyperthermic, Lithic Calcigypsids* and v) *Sandy, mixed, hyperthermic, Lithic Calcigypsids*. The soil order of the studied area is Aridisols. According to the ASLE model, the land productivity index was classified as poor (C4). Twenty crops were evaluated for their suitability in the studied area: wheat, maize, potato, sugar beet, cotton, soybean, sunflower, alfalfa, pea, citrus, olive, watermelon, apple, pear, date palm, fig, tomato, barley, faba bean, and sorghum. According to the ASLE model, suitability classes varied from very suitable (S1) to permanently non-agricultural (N2). These classes may be due to shallow soil depths, carbonate content, and low fertility

Keywords: Land capability, suitability, GIS, ASLEarid, Arid soils.

1. Introduction

Sustainable cultivation of newly reclaimed soils in arid and semi-arid regions requires an accurate monitoring of soil and water quality characteristics to relieve the pressure on food supplies for the rapidly growing population in these vulnerable areas (Abdullahi *et al.*, 2023**).** Accordingly, majority of the global most productive land resources have been exploited as the globe evolves toward utilization of vast land areas for agricultural production. For instance, there is an expected increasing shift to more marginal regions of promising agricultural productivity in arid and semi-arid regions of *Africa, Asia and South and North America*, referred to as "The Global Dryland Alliance (GDLA)"—Uniting for Food Security, which aims to consolidating mutual understanding between dry land nations (Shahid and Al-Shankiti, 2013). For decades, the major concern for sustainable soil productivity has been the population explosion in relation to the increasing demand for food crops worldwide. This problem progresses as a result of the ongoing loss of fertile land caused by rapid urbanization (Kopittke *et al.*, 2019).

In view of this, about 0.5 million hectares of most fertile soils in Egypt were lost between 1965 and 2000 due to the continuous threat of urbanization (Abd El-kawy *et al.*, 2019). In India, however, the increasing urbanization caused significant losses of about 9.36 million hectares in 1951 and 22.97 million hectares 2001, respectively (Pandey and Seto, 2015). Hence, projects involving effective management of land reclamation and cultivation are now of utmost importance to mitigate the loss of arable soils. These projects require more reliable information about soil and water resources that will be used in management of irrigated agriculture. However, there is inadequate soil data illustrating physicochemical characteristics of newly reclaimed soils in most regions. This inadequacy could be due to the insufficiency of soil data or non-accessibility of soil information in the harmonized world soil database (HWSD).

The management of land resources and their long-term viability heavily depends on this data (Omuto *et al.*, 2013). As a result, requiring a lot of efforts to make this data accessible to stakeholders, resource managers, and policymakers. Desert land reclamation is a complex and difficult process that necessitates the integration of some technological instruments and approaches to prepare the soil structure for agricultural and other uses

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(Alary *et al.*, 2018). Geographic Information Systems (GIS) and the Applied System for Land Evaluation (ASLE) are significant instruments for desert land reclamation. ASLE has been utilized to assess and calculate land capability and suitability as an index values based on specific indices, including soil characteristics, the quality of water resources, soil fertility criteria, and environmental conditions (Elnaggar *et al.*, 2016). On the other hand, ASLE employs sensors and algorithms to assess soil qualities such as texture, structure, and fertility. This knowledge is critical for determining the optimal soil management strategies and improving soil quality in desert regions. ASLE is used to track changes in soil qualities over time and evaluate the success of reclamation activities (Nada *et al.*, 2022).

Although El-Minya Governorate is considered a promising region for land reclamation due to its accessibility to logistics and irrigation water resources, the region is susceptible to desertification due to climate change threats, desertification and urbanization (Shalby *et al.*, 2023). Overexploitation of groundwater resources is also an additional threat to sustainable development in this vulnerable region. The depletion of groundwater caused by overexploitation has been associated with severe deteriorations in the quality of aquifers (Musaed *et al.*, 2024). The objective of the study is to assess the land and water resources of newly reclaimed areas west of Minya, Egypt, and to produce capability and suitability maps for agricultural purposes. These research findings may assist planners and policymakers in developing a framework for decision-making regarding long-term use of reclaimed land and water resources in the area.

2. Materials and Methods

2.1. Soil characteristics

The study area is regarded as one of the promising locations for land reclamation in the western desert, located at 27º 52′ 00"; 27º 55′ 00″ N and 29º 55′ 00″; 30º 1′ 00″ E, covering a total area of 36.76 km^2 in the western Nile River region, El Minya Governorate. Meteorological data indicated that the average minimum and maximum temperatures ranged from 3.36 to 24.55°C in winter and 19.42 to 41.99°C in summer; mean annual rainfall ranged from 12.07 mm in winter to 0.02 mm in summer; the average relative humidity was 60.25% in winter and 32.58% in summer, and wind speed ranges from 2.54 m/s in winter to 3.46 m/s in summer (National Aeronautic Space Administration) (NASA), Langley Research Centre [LaRC]; 41-years mean, 1981 to 2022; https://www.nasa.gov/langley/). The soil has an aridic moisture regime and a hyperthermic temperature regime, according to the American Soil Taxonomy (USDA, 2004).

2.2. Soil sampling and analysis

Fifty soil profiles representing different geomorphologic units of the investigated area were excavated (Fig. 1). Eighty-one soil samples were obtained to represent different layers for laboratory analyses. The soil samples were analysed for particle size distribution, pH (in the soil paste), electrical conductivity (in the soil paste extract), exchangeable sodium percentage, $CaCO_3$ % and $CaSO_4.2H_2O$% as described by (Jackson, 2005; Sparks *et al.*, 2020; Piper, 2019; Hesse and Hesse, 1971). The pH/mV/Temperature Meter (Jenway 3505 model) was used to measure soil pH in deionised (DI) water suspension (1:2.5). Soil salinity (EC) was measured in soil water extract. Total carbonate was estimated volumetrically using Collins Calcimeter and calculated as calcium carbonate. Gypsum content was determined through the acetone precipitation method. Cation Exchange Capacity (CEC) was determined by saturating the soil with ammonium acetate (1.0 M), and the Exchangeable Sodium Percentage (ESP) was calculated using the standard equation.

$$\boldsymbol{ESP = [Na - soil] * 100/CEC} \qquad \textbf{(eq 1)}$$

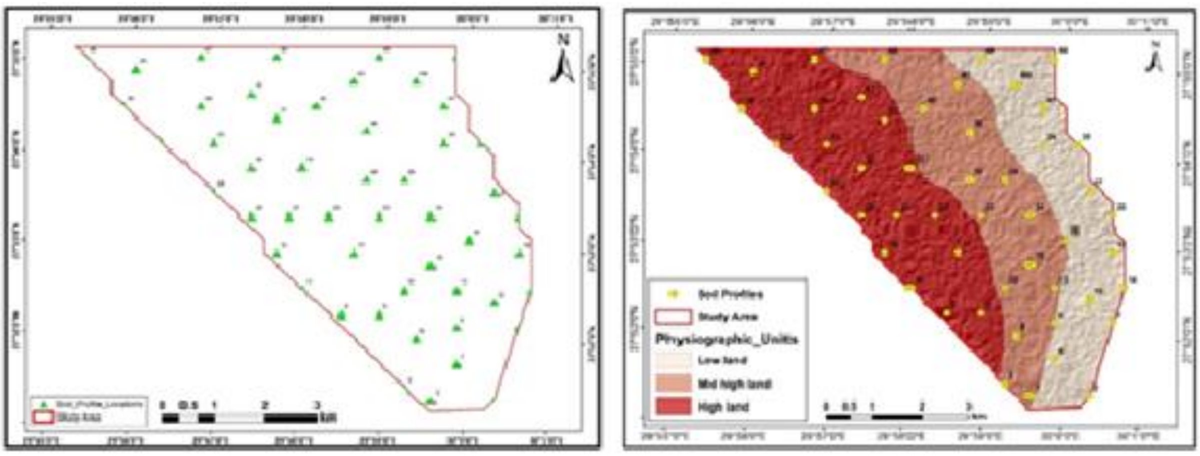

Fig. 1. Soil profile locations and physiographic units of the study area.

Deionised (DI) water extract (1:2.5) was used to determine water-soluble cations and anions: cations of Na^+, K^+ using flame photometer, Ca^{2+} and Mg^{2+} by titration with EDTA, anions of CO_3^{2-} and HCO_3^- were determined, by titration with H_2SO_4, whereas anions of Cl^- were determined by titration with $AgNO_3$. Organic matter was determined using the Walkley and Black oxidation process. Available N was determined using Kjeldahl method after extraction with 2.0 M KCl. Available P was determined spectrophotometrically following 0.5 M $NaHCO_3$ extraction (pH 8.5). The Sherwood flame photometer (MODEL 360) was used to determine available K, measured by 1.0 M $NH_4CH_3CO_2$ extraction (pH 7.0). Soil colour was defined by Munsell Colour Charts. Ordinary kriging (OK) was used to map the spatial distribution of the soil parameters in ArcGIS (version 10.5) under the Geostatistical Analyst tool. Land suitability classification was carried out using the ASLEarid model.

2.3. Groundwater sampling and analysis

Samples of groundwater were collected from a well generated from the the groundwater aquifer at coordinate 27.887305°N, 30.135084°E. This well is fed from the Nubian sandstone aquifer. It is a renewable source of water that has been used for decades and can survive delivery for many more years. Water samples were collected in 100 ml sample bottles and were immediately placed in an ice box until reaching the laboratory for analysis. Values of EC, pH, soluble ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}), as well as concentrations of Fe, Zn, Cu and Mn were analysed following similar procedures mentioned above. The irrigation water quality criteria, such as residual sodium bicarbonate (RSBC), Na%, residual sodium carbonate (RSC), sodium adsorption ratio (SAR), kelly's ratio (KR), magnesium adsorption ratio (MAR), potential salinity (PS), and permeability index (PI) were computed following the procedures described by (Mosa *et al.*, 2023).

$$\boldsymbol{Sodium\ percentage\ (Na\%) = (Na^+/Na^+ + K^+ + Ca^{2+} + Mg^{2+})x100} \qquad \textbf{(eq 2)}$$

$$\boldsymbol{Sodium\ Adsorption\ Ratio\ (SAR) = Na^+/\sqrt{Ca^{2+} + Mg^{2+}/2}} \qquad \textbf{(eq 3)}$$

$$\boldsymbol{Residual\ Sodium\ Carbonate\ (RSC) = \left(CO_3{}^{2-} + HCO_3{}^{-}\right) - (Ca^{2+} + Mg^{2+})} \qquad \textbf{(eq 4)}$$

$$\boldsymbol{Residual\ Sodium\ BiCarbonate\ (RSBC) = HCO_3{}^{-} - Ca^{2+}} \qquad \textbf{(eq 5)}$$

$$\boldsymbol{Kelly's\ Ratio\ (KR) = Na^+/Ca^{2+} + Mg^{2+}} \qquad \textbf{(eq 6)}$$

$$\boldsymbol{Magnesium\ Adsorption\ Ratio\ (MAR) = Mg^{2+}/Ca^{2+} + Mg^{2+}} \qquad \textbf{(eq 7)}$$

$$\boldsymbol{Permeability\ Index\ (PI) = ((Na^+ + \sqrt{HCO_3{}^{-}})/(Ca^{2+} + Mg^{2+} + Na^+))\ x100} \qquad \textbf{(eq 8)}$$

$$\boldsymbol{Potential\ Salinity\ (PS) = Cl^- + 1/2SO_4{}^{2-}} \qquad \textbf{(eq 9)}$$

2.4. ASLE-arid application

ASLEarid was used to evaluate land capabilities and suitability of the studied area. The ASLE capability model predicts the overall land capability for a wide range of potential agricultural uses. This model determines the final soil capability index and crop suitability classifications (Nada et al. 2022). Several basic parameters were used in the process, including soil physical and chemical properties, soil fertility, as well as irrigation water quality. The procedural concepts are based on the FAO (1976) land evaluation framework and the approach described by Nada et al. (2022**)**. The capability evaluation consists of five classes for reclamation and agricultural land capability: Soil properties, water quality, soil fertility, environmental parameters, and climate data were all input into the ASLE-Arid model to determine land capability and suitability. The ASLE is a soil suitability assessment model that determines the level of suitability for land use. Each crop is classified based on it suitability. There are six suitability classes: S1=very suitable (>80%), S2=suitable (60-80%), S3=moderately suitable (40-60%), S4=marginally suitable (20-40%), N1=currently unsuitable (10-29%), and N2=non-agricultural (<10%). The elements impacting the land suitability for certain crop are the physical features such as profile depth, clay content, land shapes, slope and surface level, which influence soil-water interactions. The chemical characteristics, including EC, CEC, pH, ESP, $CaCO_3$, and gypsum, contribute to determining soil fertility. Twenty crops (sorghum, wheat, maize, barley, faba bean, potato, sugar beet, peanut, cotton and alfalfa, tomato, pepper, watermelon, pea, citrus, olive, apple, date palm, fig and pear) were chosen to determine their suitability for cultivation in the studied area.

2.5. Geospatial mapping

ArcGIS was used for geospatial and mapping of the studied area. Ordinary kriging, using the Geostatistical Analyst-extension in ArcGIS Desktop (ver. 10.5), was deployed to carry out surface interpolation of soil properties. Kriging, a spatial interpolation method, uses a weighted sum of measured values to predict values at unmeasured locations, as indicated in the formula below **(**Elnaggar 2020**)**.

$$\boldsymbol{Z(S0) = \sum_{i=1}^{n} \lambda i \, Z(Si)} \qquad \textbf{(eq 10)}$$

Where: Z(S0) = prediction location, λi = an unknown weight for the measured value at the ith location, n = number of measured values, Z(Si) the measured value at the ith location.

3. Results

3.1. Description of soil classification

The soils were classified based on aridic moisture and hyperthermic temperature regimes as follows: i) soil moisture and temperature regimes, ii) morphological characteristics, iii) chemical and mineralogical compositions, and iv) presence/absence of diagnostic horizons. These soil contain one or more of the salic, gypsic, and calcic diagnostic horizons. In this study area, soils of this order are commonly classified into two suborders of Aridisols namely: Calcids and Gypsids, two Great Groups Calcigypsids and Haplocalcids, and three Subgroups were recognized: *Lithic Calcigypsids*, *Typic Calcigypsids*, and *Typic Haplocalcids*. Five soil map units (SMUs) were identified in the studied area (Fig. 2) according to the USDA Soil Classification System (Taxonomy, 2014)**.** The soil map units cover areas of 9.08, 4.60, 6.37, 9.786 and 6.93 km^2, with corresponding percentages of 24.70, 12.53, 17.32, 26.60 and 18.86% respectively. These classified soils and their representative profile numbers are listed below**:** i) *Deep sandy, mixed, hyperthermic*, *Typic Haplocalcids* (2, 7, 10, 13, 14, 18, 19, 24, 25, 27, 34, 35, 41 and 50), ii) *Shallow sandy skeletal, mixed, hyperthermic, Typic Haplocalcids* (20, 21, 26, 30, 31, 37 and 40), iii) *Sandy skeletal, mixed, hyperthermic, Typic Calcigypsids* (6, 12, 15, 17, 22, 23, 28, 29, 36, 43, 44 and 49), iv) *Sandy skeletal, mixed, hyperthermic, Lithic Calcigypsids* (1, 3, 4, 5, 8, 9, 11 and 16) and v) *Sandy, mixed, hyperthermic, Lithic Calcigypsids* (32, 33, 38, 39, 42, 45, 46, 47 and 48)(Table 1).

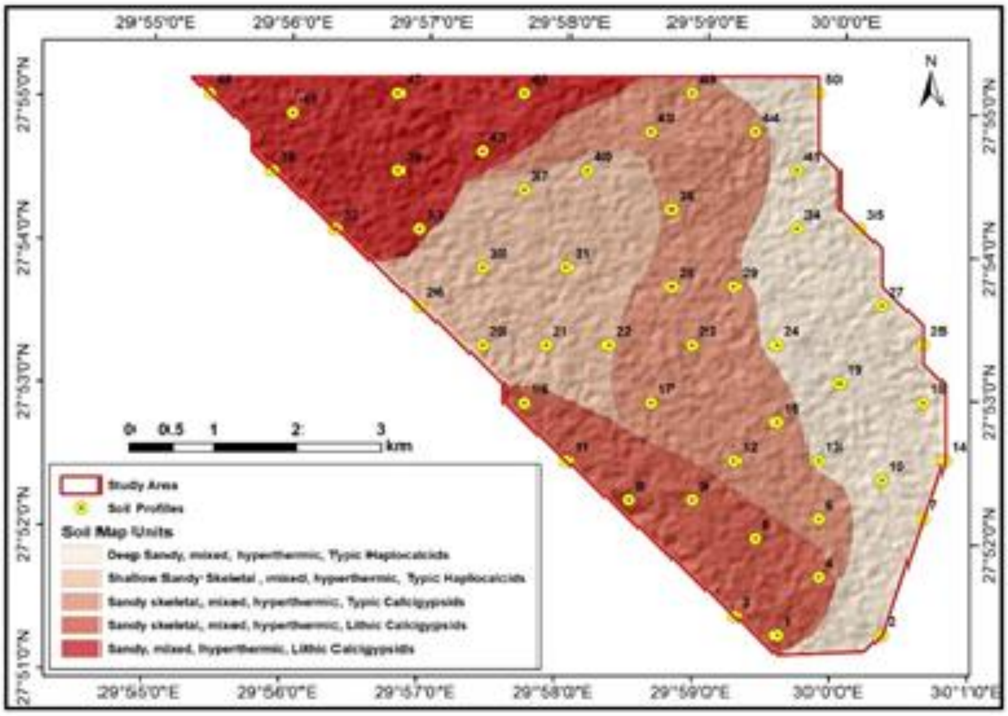

Fig. 2. Soil map units (SMUs) of the studied area.

Table 1. Soil classification of the studied area.

Geomorphic Units	Prof. No.	Order	Suborder	Great group	Subgreat group	Family
Low land	2, 7, 10, 14, 18, 19, 25, 27, 34, 35, 41, 50		*Calcids*	Haplocalcids	Typic Haplocalcids	Deep sandy, mixed, hyperthermic
	6, 44, 49		*Gypsids*	Calcigypsids	Typic Calcigypsids	Sandy skeletal, mixed, hyperthermic
	4				Lithic Calcigypsids	Sandy skeletal, mixed, hyperthermic
Mid-high land	13, 24	*Aridisols*	*Calcids*	Haplocalcids	Typic Haplocalcids	Deep sandy, mixed, hyperthermic
	40				Typic Haplocalcids	Shallow sandy, skeletal, mixed, hyperthermic
	12, 15, 23, 28, 29, 36, 43		*Gypsids*	Calcigypsids	Typic Calcigypsids	Sandy skeletal, mixed, hyperthermic
	1, 3, 5,				Lithic Calcigypsids	Sandy skeletal, mixed, hyperthermic
	48				Lithic Calcigypsids	Sandy, mixed, hyperthermic
High land	20, 21, 26, 30, 31, 37		*Calcids*	Haplocalcids	Typic Haplocalcids	Shallow sandy, skeletal, mixed, hyperthermic
	17, 22		*Gypsids*	Calcigypsids	Typic Calcigypsids	Sandy skeletal, mixed, hyperthermic
	8, 9, 11, 16				Lithic Calcigypsids	Sandy skeletal, mixed, hyperthermic
	32, 33, 38, 39, 42, 45, 46, 47				Lithic Calcigypsids	Sandy, mixed, hyperthermic

3.2. Evaluation of Land capability

The ASLE model was utilised to assess land capability of soils in the study area. This model forecasts the general land use potential for a variety of applications, primarily agricultural and non-agricultural, based on soil type and features. Additionally, based on capability or constraints, the classification aids in estimating soil resources accessible for various purposes. The land capability classes range from C1= Excellent, C2= Good, C3= Fair, C4= Poor, and C5= Very poor, to C6= Non-agricultural. The soil and fertility indices of the studied area were generally poor to non-agriculture (9.97, 49.11 and 43.04%) and (10.04, 40.85 and 49.11%), respectively. Whereas land capability index was (100%) poor (C4). These soils have some limiting constraints that may reduce their productivity, such as bio-climatic factors, soil factors (soil depth, soil texture, soil stoniness%, and soil salinity dS/m), and other physical indicators. However, proper management approaches could improve capability of these soils.

3.3. Evaluation of Land Suitability

Results of land suitability showed that the area under study offers a wide range of potentialities for field crop production under irrigation, ranging from very suitable to non-agricultural, assuming water requirements are fully provided. Twenty crops were chosen to assess their suitability for agriculture, which include field crops (sorghum, wheat, maize, barley, faba bean, potato, sugar beet, peanut, cotton and alfalfa), vegetable crops (tomato, pepper, watermelon and pea,) and fruit trees (citrus, olive, apple, date palm, fig and pear). Based on the ASLE model, these crops ranged from very suitable to non-agricultural for crops in the studied area, with suitability classes ranging from very suitable (S1), suitable (S2), moderately suitable (S3), marginally suitable (S4), currently unsuitable (N1), and permanently non-agricultural (N2). The land suitability of various crops produced by ASLE model is presented in Table 2. Approximately 2.44 and 2.97% of the study area were very suitable (S1), suitable (46.08 and 48.58%), and moderately suitable (51.48 and 48.45%) for wheat and barley (Fig. 3), respectively.

Sugar beet, alfalfa, sorghum, and tomato were found to be suitable (46.11, 30.16, 51.55, and 57.87%), moderately suitable (46.91, 33.99, 42.90, and 32.28%), and marginally suitable (6.98, 35.85, 5.56, and 9.85%) for cultivation in this location (Fig. 4). For maize and faba bean cultivation, approximately (19.20 and 18.67%) of the area were suitable, (24.77 and 19.88%) moderately acceptable, (28.11 and 21.35%) marginally suitable, (20.53 and 29.71%) currently unsuitable, and (7.38 and 10.38%) permanently non-agricultural (Fig. 5). Citrus, apple and pear about (14.79, 15.46 and 13.06%) were moderately suitable, (38.49, 81.38 and 83.59%) were currently unsuitable and (46.72, 3.16 and 3.34%) were permanently non-agricultural (Fig. 6). Similarly, crops such as peanut, cotton, watermelon and pepper were suitable (35.96, 31.06, 35.60 and 76.01%, respectively), moderately suitable (49.36, 35.64, 51.93 and 8.44%, respectively) and currently unsuitable (14.69, 33.29, 12.47 and 15.55%, respectively) (Fig. 7).

Other crops including fig, date palm and olive were suitable (4.82, 5.48 and 4.47%, respectively), marginally suitable (58.46, 61.82 and 41.77%, respectively) and currently unsuitable (36.72, 32.71 and 53.76%, respectively) as demonstrated in Fig. 8. Regarding cultivation of pea and potato, data pointed to suitable cultivation (30.47 and 30.51%, respectively), moderately suitable (16.35 and 19.99%, respectively), currently unsuitable (27.94 and 31.78%, respectively), and permanently non-agricultural (25.25 and 17.71%, respectively) (Fig. 9).

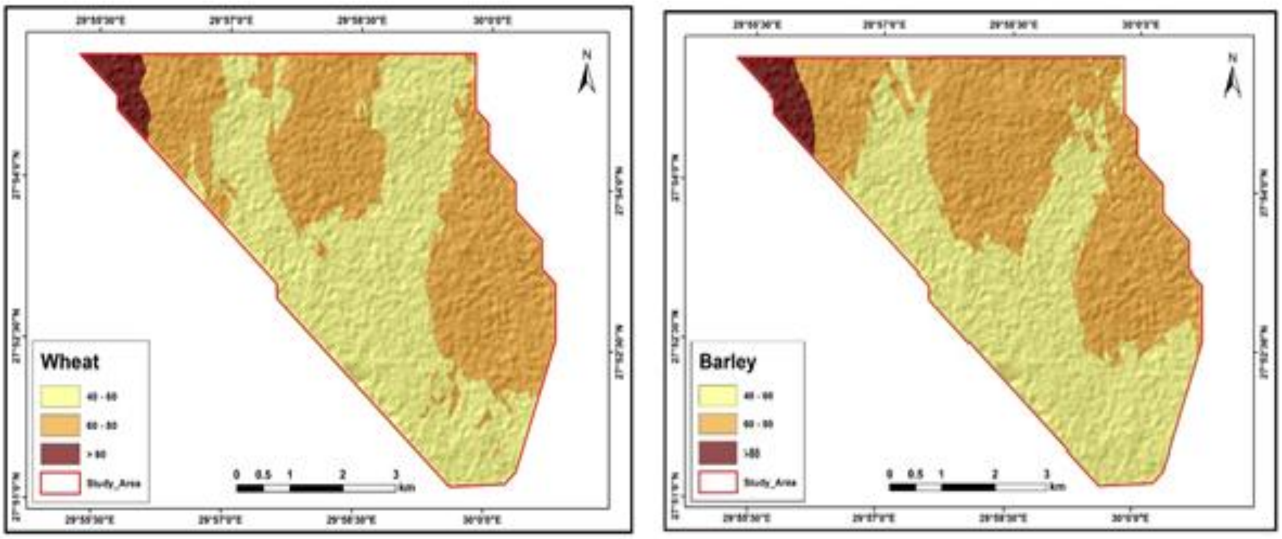

Fig. 3. Suitability map of wheat and barley cultivation in the studied area.

Table 2. The percentages of each land suitability class of the studied area.

Crop	S1%	S2%	S3%	S4%	N1%	N2%
Wheat	2.44	46.08	51.48	--	--	--
Maize	--	19.20	24.77	28.11	20.53	7.38
Barley	2.97	48.58	48.45	--	--	--
Faba bean	--	18.67	19.88	21.35	29.71	10.38
Peanut	--	35.96	49.36	--	14.69	--
Sugar beet	--	46.11	46.91	6.98	--	--
Cotton	--	31.06	35.64	--	33.29	--
Water melon	--	35.60	51.93	--	12.47	--
Alfalfa	--	30.16	33.99	35.85	--	--
Pea	--	30.47	16.35	--	27.94	25.25
Sorghum	--	51.55	42.90	5.56	--	--
Potato	--	30.51	19.99	--	31.78	17.71
Tomato	--	57.87	32.28	9.85	--	--
Pepper	--	76.01	8.44	--	15.55	--
Citrus	--	--	14.79	--	38.49	46.72
Fig	--	4.82	--	58.46	36.72	--
Date palm	--	5.48	--	61.82	32.71	--
Olive	--	4.47	--	41.77	53.76	--
Apple	--	--	15.46	--	81.38	3.16
Pear	--	--	13.06	--	83.59	3.34

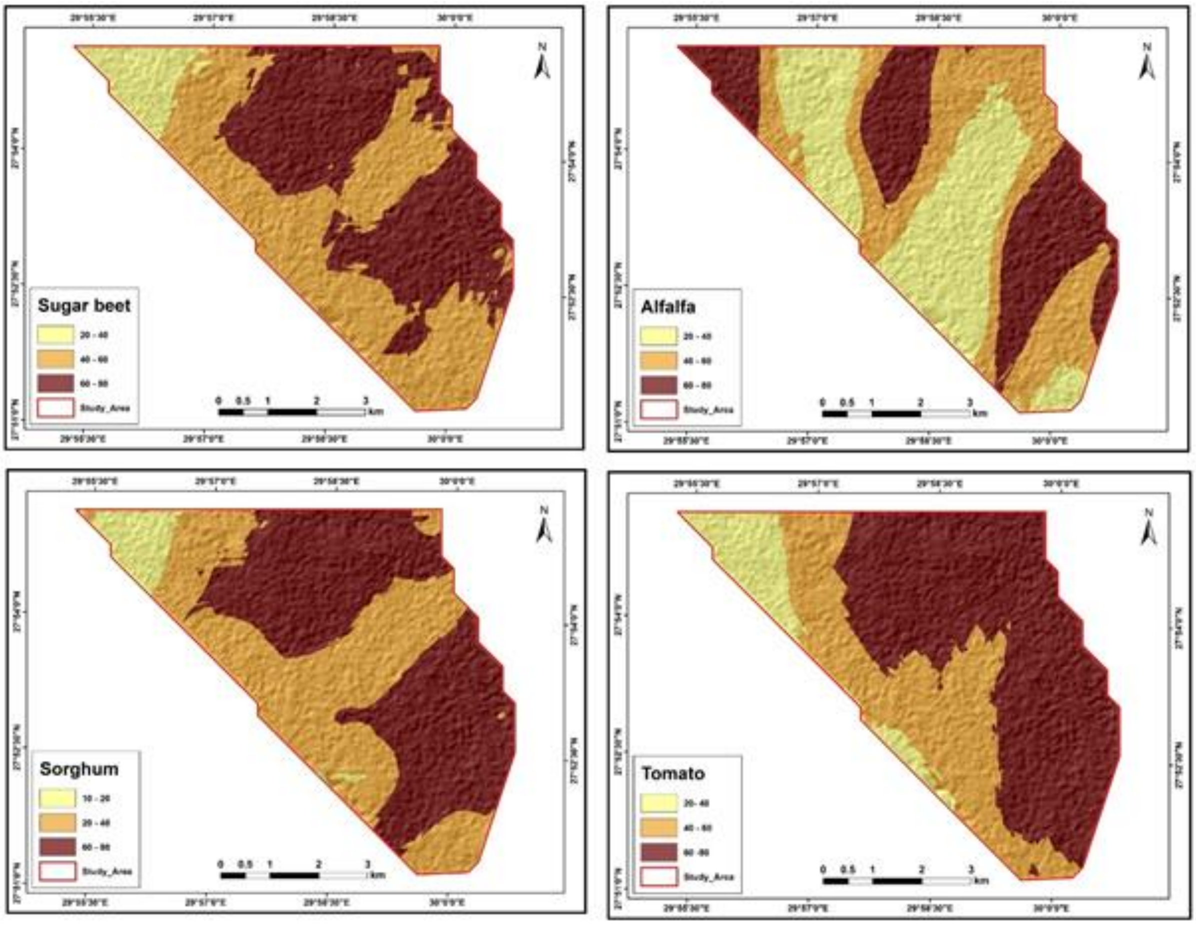

Fig. 4. Suitability map of sugar beet, alfalfa, sorghum and tomato cultivation in the studied area.

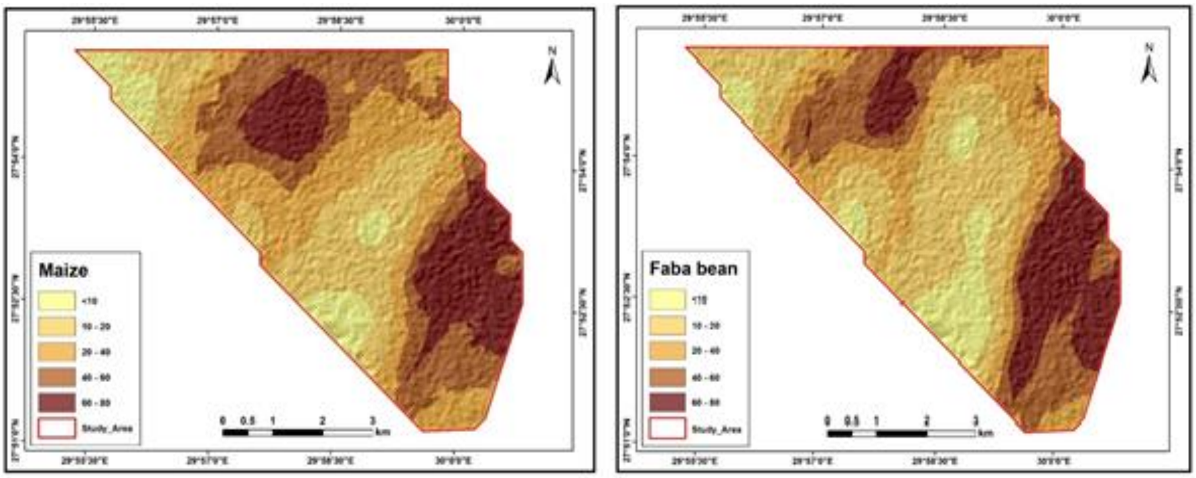

Fig. 5. Suitability map of maize and faba beans cultivation on the studied area.

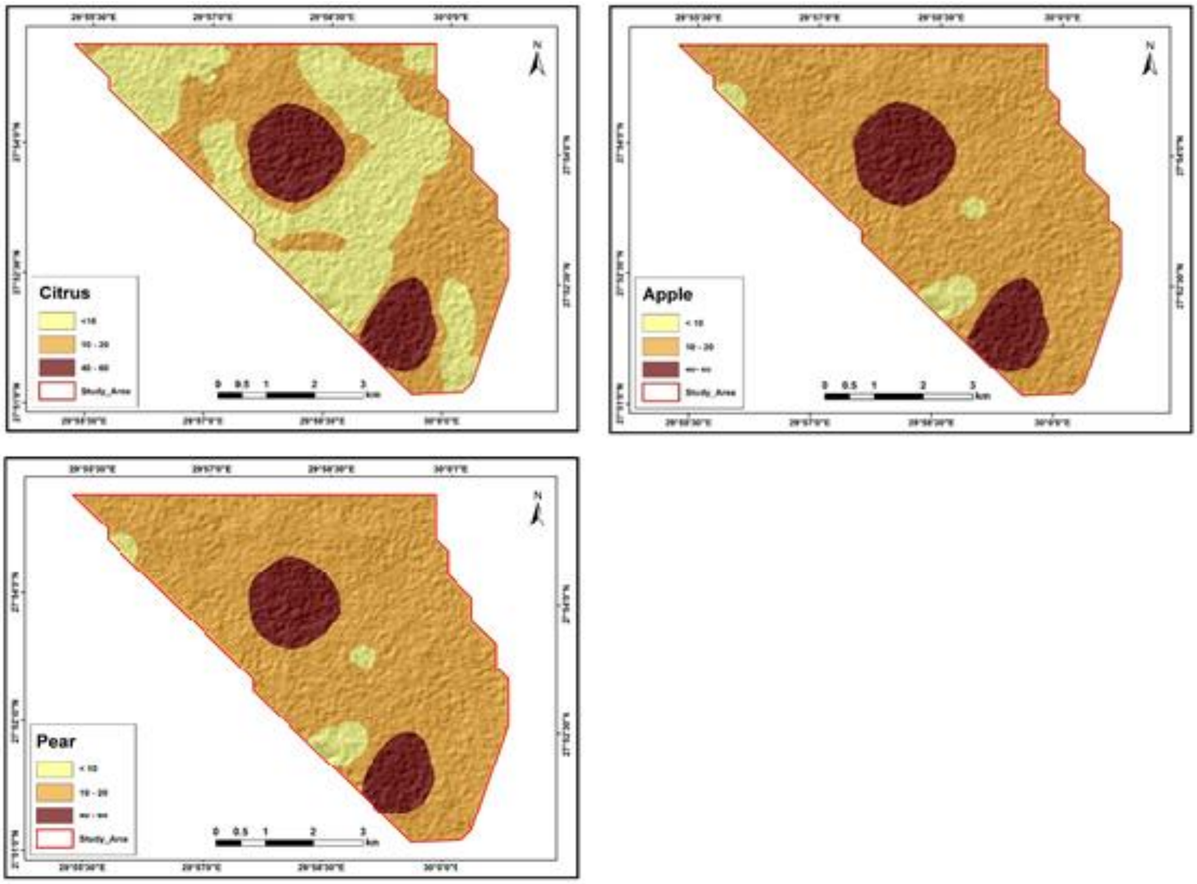

Fig. 6. Suitability map of citrus, apple and pear cultivation on the studied area.

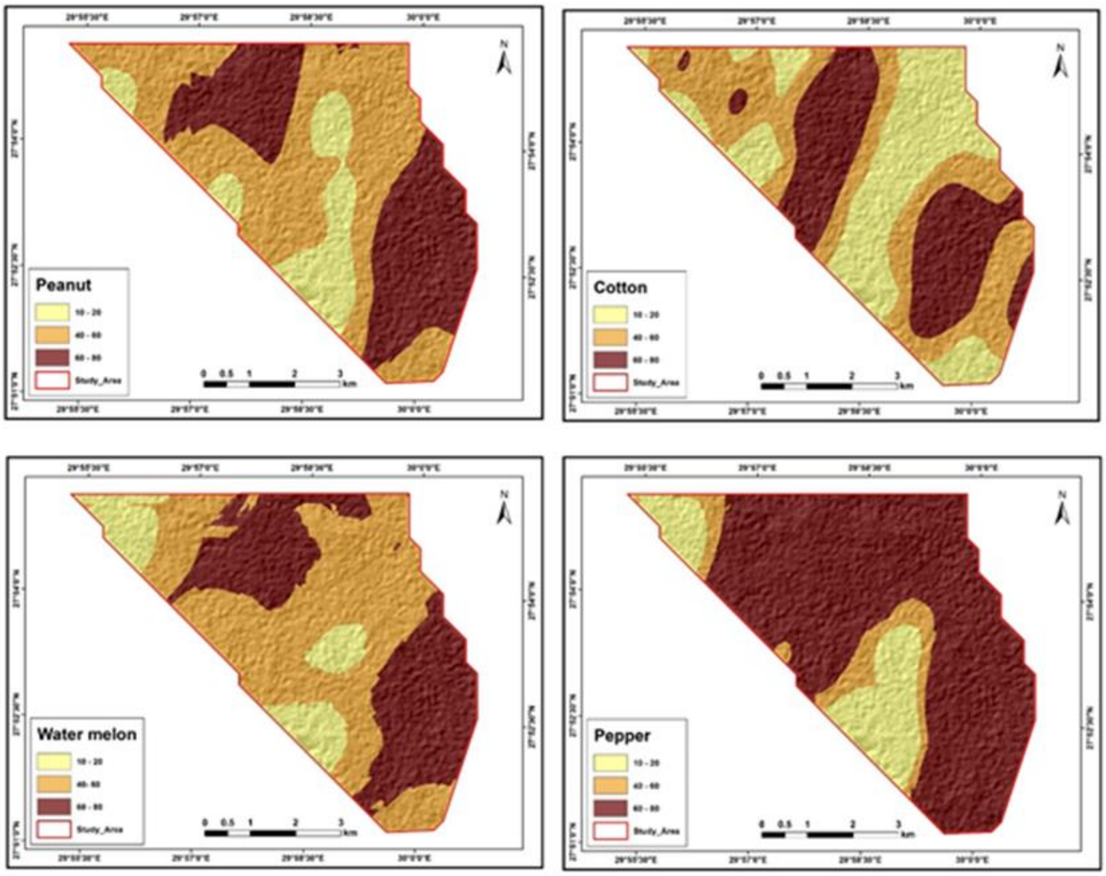

Fig. 7. Suitability map of peanut, cotton, water melon and pepper cultivation on the studied.

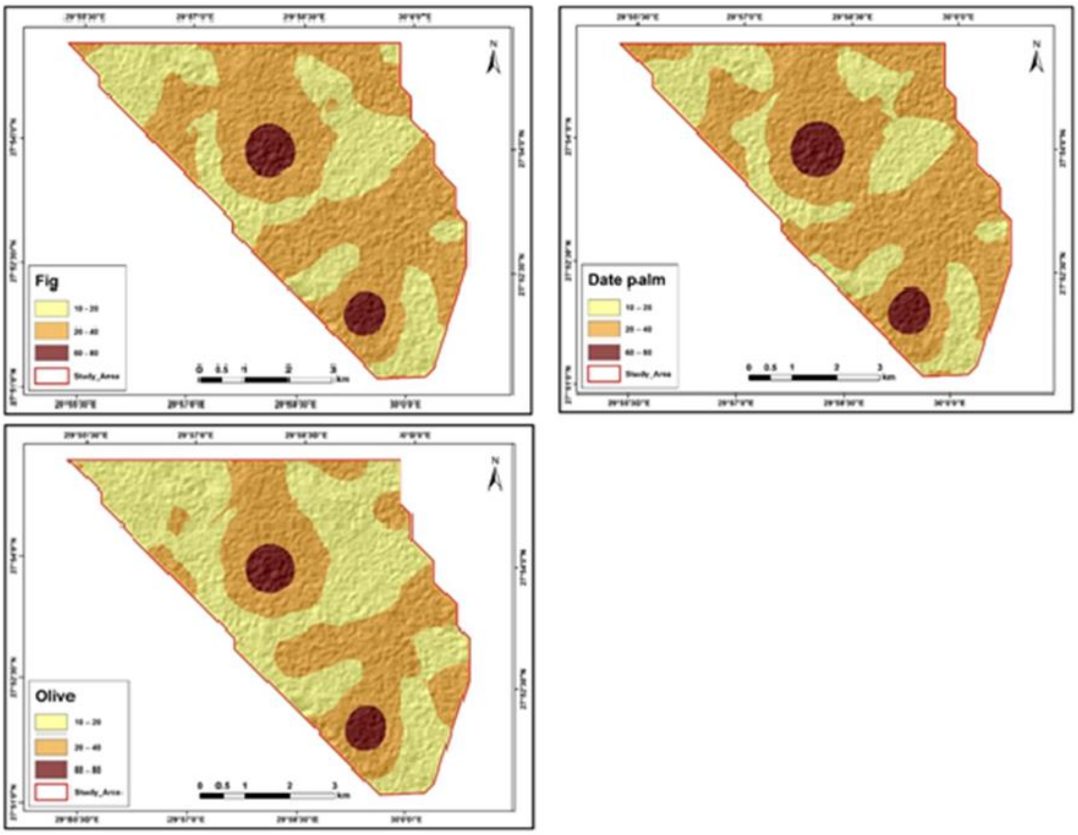

Fig. 8 Suitability map of fig, date palm and olive cultivation in the studied area.

This finding suggests that land in Classes S4 and S3 requires a moderate level of soil amendment to increase crop productivity. Class S2 requires minimum soil addition, whereas class S1 does not require any amendment for crop production. On the other hand, Classes N1 and N2 require a significant amount of soil amendment to increase production potential. The findings showed that general constraints factors, such as very low fertility levels, shallow soil depth, sandy nature, and high calcium content in some soil profiles, are among the limiting factors for growing crops, such as fruit trees.

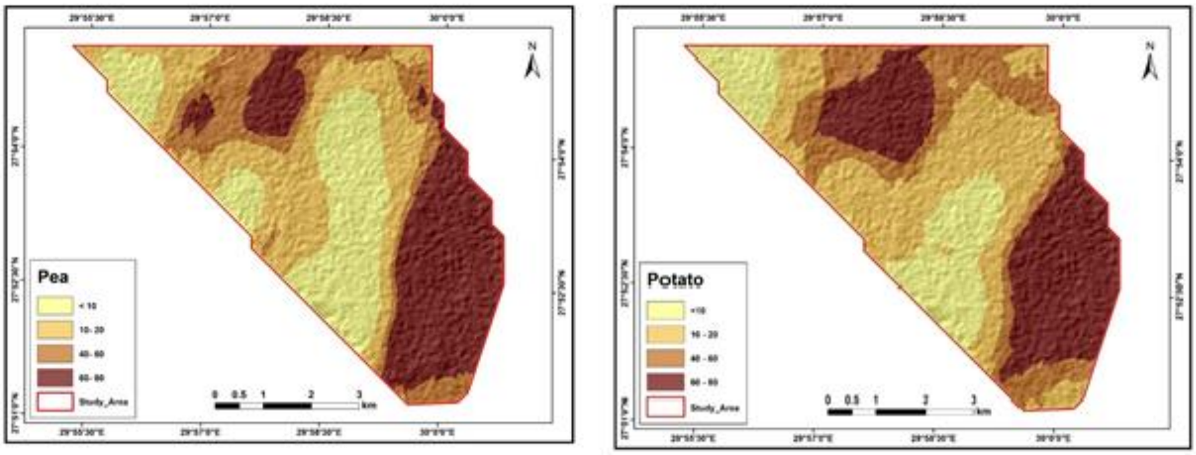

Fig. 9. Suitability map of pea and potato cultivation on the studied area.

4. Evaluation of groundwater quality of the studied area

The pH and salinity (EC) values were 8.15 and 2.04 dS/m, respectively. The pH value shows the typical alkalinity nature of Egyptian water, whereas the EC level of irrigation water indicates a moderate level of limitations according to the guidelines of the Food and Agriculture Organization (FAO) (Ayers and Westcot, 1985). The salinity was owed to the high quantities of soluble cations (Na^+, Ca^{2+} and Mg^{2+}) and anions (Cl^-, HCO_3^- and SO_4^{2-}). The harmful effects of sodium, represented by Na%, SAR, and KR values, was 45.24%, 3.93, and 6.54, respectively. This SAR value indicated a slight to moderate level of constraint in use due to the preponderance of Na^+ ions in the water (>26%). However, the KR criterion value indicated suitability for use in irrigation. According to Gupta and Gupta (1987), a low MAR value (<50) indicates that the water is suitable for irrigation. The computed values of MAR, RSC and RSBC computed were 5.83, -10.00 cmol/L and -5.00 cmol/L respectively. The negative values for RSC and RSBC indicate the high proportion of Ca^{2+} and Mg^{2+} ions, as well as limited potential for sodium carbonate deposition in the soil medium. According to the permeability index value (50.54%), the water quality is classified as (C2), indicating that it is suitable for irrigation purposes (Rawat *et al.*, 2018) (Table 3)

5. Discussion

Land reclamation is regarded as an important project in Egypt, and El-Minya in the western desert is considered as a promising location. Fifty soil profiles were used to represent the geomorphological units of the studied area, identifying five units, namely; i) *Deep sandy, mixed, hyperthermic, Typic Haplocalcids* ii) *Shallow sandy skeletal, mixed, hyperthermic, Typic Haplocalcids* iii) *Sandy skeletal, mixed, hyperthermic, Typic Calcigypsids* iv) *Sandy skeletal, mixed, hyperthermic, Lithic Calcigypsids* and v) *Sandy, mixed, hyperthermic, Lithic Calcigypsids*. Soil order in the studied area is Aridisols. Land suitability evaluation requires specifying the crop rewuirements and their compatibility with the type/quality of the land and soil factors. Land suitability analysis is essential for long-term agricultural production, and one of the most useful tools for land resource planning and management (Tadesse and Negese, 2020; Taghizadeh-Mehrjardi *et al.*, 2020). The ASLE model was used to evaluate the land suitability classification of soils in the West part of Minya Governorate, and to conduct an agro-ecological assessment of the study area for various crop varieties. Soil qualities, water quality, soil fertility, environmental parameters, and climate were all used to calculate the suitability index for various crops.

Table 3. Soluble ions and chemical properties of Irrigation well in the studied area.

Soluble ions	Values
Na (cmol/l)	9.22
K (cmol/l)	0.16
Ca (cmol/l)	6.00
Mg (cmol/l)	5.00
CO_3 (cmol/l)	ND
HCO_3 (cmol/l)	1.00
Cl (cmol/l)	11.90
SO_4 (cmol/l)	7.48
Chemical properties	
pH	8.15
Electrical conductivity (dS/m)	2.04
Na (%)	45.24
SAR	3.93
RSC	-10.00
RSBC	-5.00
KR	6.54
MAR	5.83
PI	50.54
Fe (ppm)	ND
Zn (ppm)	0.52
Cu (ppm)	0.04
Mn (ppm)	ND

Based on the ASLE model,the land productivity index was classified as poor (C4). The following crops were evaluated for their suitability: wheat, maize, potato, sugar beet, cotton, soybean, sunflower, alfalfa, pea, citrus, olive, watermelon, apple, pear, date palm, fig, tomato, barley, faba bean, and sorghum. The suitability classes ranged from very suitable (S1) to permanently non-agricultural (N2). These classes could be as a result of shallow soil depths, high carbonate content, and low fertility. For the sustainable management of such soil charactersitcs, mechanical leveling and soil mulching should be considered to alleviate potential erosion of the surface soil layer. Furthermore, continuous application of organic matter should be adopted in order to improve water and nutrient supply capacity. Furthmore, acidifying materials (e.g. ammonium/potassium sulfate) should be applied to minimize soil pH and reduce the hazardous effects of carbonate. For soils with low suitability, pasture and forestry would be the optimum cultivation choise due to their minimal water ad nutrients requirements.

The pH value of groundwater shows the peculiar alkaline nature of Egyptian water. The concentration of EC in irrigation water shows moderate restrictions according to the guidelines of the Food and Agriculture Organization (FAO). The salinity is due to the high amounts of soluble cations and anions. The harmful effect of sodium, given by Na%, SAR, and KR values, was 45.24%, 3.93%, and 6.54%, respectively. This SAR value (>26%) indicated a slight to moderate level of constraint due to dominancy of Na^+ ions in the water. Nevertheless, the KR value indicates suitability for use in irrigation. The low MAR value (<50) shows that the water is suitable for irrigation. The computed values of MAR, RSC and RSBC were 5.83, -10.00 cmol/L and -5.00 cmol/L respectively. The negative values for RSC and RSBC indicate a limited potential for sodium carbonate deposition in the soil medium, as well as a high proportion of Ca^{2+} and Mg^{2+} ions. According to the permeability index (50.54%), the water quality is classified as (C2), demonstrate that it is suitable for irrigation purposes. The land capability and suitability maps were produced using ArcGIS (ver. 10.5).

6. Conclusions

The evaluation of land capability and suitability can help in actualizing sustainable crop production for the development of agriculture in the studied area. Geographic Information System (GIS) and ALSE-arid model were good in assessing land capability and suitability in the region. The study evaluate soil capability and suitability for crop production and also identified the main constraints that hindered agricultural progress in the study area. The soils were classified as C4 class (poor capability) according to the ALSE-Arid model. The predominant limiting factors of soil capability were soil texture, shallow depths, and low soil fertility. However, these limitations can be enhanced through suitable management practices. According to the ALES program, the soils of the studied area varied in suitability index from very suitable (S1) to permanently non-agricultural (N2). The results obtained play an important role in choosing the most appropriate crops in the research area. Land evaluation contributes by guiding decision-makers in the sustainable management of agricultural resources.

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