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COMPARISON AMONG SOME LAND EVALUATION METHODS ON DESERT ECOSYSTEM IN EGYPT
CASE STUDY: AL-SALHEYIA AREA, EAST OF DELTA.

Elwan A.A. and Khalifa M.E.A.

Pedology Department, Water Resources and Desert Soils Division, Desert Research Center (DRC), Cairo, 11753, Egypt

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ABSTRACT: Land evaluation methods differ in approach and have not consistently shown positive outcomes outside of the areas where they were developed. The methods of USDA land capability classification (LCC), Storie index, fertility capability classification (FCC), and qualitative desert land potentiality evaluation (Q_LDLPE) were used to evaluate 41500 Faddans (≈17430 hectares) of agricultural lands in the Al-Salheyia area, east of Delta, Egypt, to see how well they agreed and performed. Several soil parameters relating to pedomorphological, physicochemical, and fertility properties were investigated. Five soil mapping units were determined based on solum depth, texture, soil salinity, and $CaCO_3$ content. The soils ranged in depth from deep to moderately deep, in texture from coarse to fine, in salinity from nonsaline to strongly salinity, and in calcareousness from moderately to strongly calcareous. In terms of LCC, the lands were classified as arable class-III (5900 Faddans; 14.2%), arable class-IV (29450 Faddans; 71%), and nonarable class-V (6150 Faddans; 14.8%). The Storie index classified the soils tested into four categories: fair (5900 Faddans), poor (10250 Faddans), very poor (6500 Faddans), and nonagricultural soils (18850 Faddans). According to the LCC and Storie index, the soils were primarily limited by coarse soil texture, soil salinity, and wetness. Fine textured soils were limited by water logging 'g+', severe salinity 's', and high $CaCO_3$ 'b'. In contrast, according to FCC criteria, coarse-textured soils were limited by low ECEC 'e', low OM 'm', and dry season 'd'. Based on Q_LDLPE ratings, three potentiality classes were created: slight (6150 Faddans), moderate (18600 Faddans), and high (16750 Faddans). Although correlation analysis revealed a relationship between LCC, Q_LDLPE, and FCC, the Storie index had lower correlation coefficient values. The kappa coefficient (k) was determined between the land evaluation results and observed actual crop yield in tested soils. The statistical study revealed the most significant values of k, ranging from moderate to perfect agreement (0.59-0.94) between the Q_LDLPE and observed crop production, indicating that this approach is a powerful tool for predicting the natural resources of the desert environment. On the other hand, the Storie index demonstrated a poor concordance between its identified classes and the actual performance of the cultivated soils. As a result, the Q_LDLPE outperformed other approaches. Other methods of FCC and LCC have similar lower agreement values between their results and observed crop production. This shortage is because the Storie index and LCC gave the lowest score ratings for coarse sand texture and associated attributes. As a result, they classified most of the desert soils under investigation as nonarable lands, even though these soils are already cultivated and produce rich crops in an economically viable manner. Furthermore, the Storie index and LCC have fallen short of covering all soil, socioeconomic, political, and environmental criteria. As a result, these methodologies are insufficient and appear unjust for estimating the productivity potential of desert lands. This study found that Q_LDLPE is a qualitative multidisciplinary method and specialized tool for desert resource ecosystem optimization and sustainable management. Furthermore, all tested methods are classified as qualitative approaches that do not consider input or output measures. In the future, quantitative desert land potentiality evaluation (Q_NDLPE) methodology based on quantitative, economic, and profit measures should be designated and tested for economic land evaluation and valuation in the desert ecosystem.

Keywords: LCC, FCC, Q_LDLPE, Storie Index, Land Evaluation, Kappa Coefficient, Desert Soils.

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*Corresponding author: dr.elwan@drc.gov.eg

INTRODUCTION

The desert ecosystem is defined as areas with high evaporation, meager precipitation, and little vegetation related to herbaceous plants and shrubs (Khan *et al.*, 2017; Wang *et al.*, 2022). The desert ecosystem provides services such as sand fixation, oxygen release, nitrogen fixation, soil conservation, water resource control, culture, and biodiversity conservation (Wen *et al.*, 2023). Desert ecosystems encompass around 22% of the global geographical surface and support approximately three billion people worldwide, comprising semi-desert, tropical, subtropical, and temperate ecosystems (Wang *et al.*, 2022). The ecological conditions of the desert ecosystem are particularly vulnerable (Whitford, 2002). Its growth and origin result from arid climate, vegetation evolution, and surface processes (Iknayan and Beissinger, 2018). Based on aridity, the desert ecosystem is classified as severe arid, arid, or semiarid (Meigs, 1953; Wang *et al.*, 2022).

Arid deserts have deficient precipitation and little or no vegetation. Elwan (2013) described it as being covered with sand and weathered rocks, with low chemical weathering confined to the emission of weathering products. Poor soil aggregation, low nutrients, low water holding capacity, and low clay content characterize arid desert soils (Elwan and Sivasamy, 2013a; Tercan, 2021). The main limitations of these soils are their coarse texture and low water retention. As a result, most land evaluation systems identified arid soils as unsuitable for agriculture, misleading policymakers and leaving these resources out of agricultural development projects (Elwan, 2019). With appropriate irrigation and fertilization procedures, these soils can produce high agricultural yields (Wubalem, 2023).

Egypt is a desert country in northern Africa. It has a land area of about a million square kilometers. It is primarily desert, except for a few agricultural sections in the Delta and the surrounding areas around the Nile (Ahmed *et al.*, 2023). Egypt's climate is hot, arid, and dominated by the desert. It has a hot and dry summer season and a warm winter with little precipitation along the coast. Temperatures in the inland desert range from 10°C at night to 41°C during the day during the summer. Temperatures in the winter range from 5°C at night to 19°C during the day (Egyptian Meteorological Authority, 2022).

Soil reclamation efforts in the desert region are critical for the country's growth. Egypt's administrations make significant efforts to increase land reclamation. New desert communities and land reclamation projects have lately been created east of the Nile Delta, such as the tenth of Ramadan city, Al-Salheyia area, and Al-Mollak reclamation projects. Groundwater is a primary source of household water and irrigation in the Al-Salheyia area. Waterlogging impacted the reclaimed areas of the Al-Salheyia project due to increased shallow groundwater reaching the surface investigated land (Awad and El Fakharany, 2020). The depth into groundwater ranged from 1.3 m in New Al-Salheyia to 20 m near Ismailia Canal (Awad and El Fakharany, 2020). Agricultural activities and irrigation systems significantly impact groundwater tables and water quality in the Quaternary aquifer of the El-Salhyia area (Mabrouk *et al.*, 2016).

Land and water are considered vital resources of every nation because they are the primary suppliers of most elements required by humans (Hu *et al.*, 2023). On the other hand, food insecurity plagues several developing countries because products cultivated in desert soils lack essential minerals and are insufficient for food security since land use is not effectively analyzed and planned (Gao and Li, 2022). Most worldwide land evaluation methods do not consider land characteristics relevant to people and the environment in locations other than where they were devised (Elwan, 2013; Ghobadi *et al.*, 2021). As a result, these methods must be tested to their ability and performance in other locations worldwide (Ghobadi *et al.*, 2021; Gao and Li, 2022). Fertility Capability Classification (FCC), which identifies soil fertility constraints (Sanchez *et al.*, 2003), and Land Capability Classification (LCC), which examines land capability based on physical features (Klingebiel and Montgomery, 1961), are two of the most often used approaches. Both methodologies are combined to widen the scope of evaluation and improve interpretation (Oko-Oboh *et al.*, 2017). Both methods are multifunctional in determining soil quality (Ghobadi *et al.*, 2021). Rossiter (1994) criticized the FCC for failing to rank soils. The Storie Index was developed in California and first published in the 1930s to appraise citrus farms. O'Geen *et al.* (2008) have frequently updated it. Many other parts of the world have developed adaptations of the approach. Initially, the Storie index was only used with three components. They are as follows: soil development degree (factor A), topsoil soil texture (factor B), and alkalinity, slope, and drainage (factor C). In 1944 and later editions, the former factor C was renamed factor X, and a new factor C was established to evaluate slope. Each element is multiplied by a decimal and scored as a percentage. The final index is given in percentage form. When more than one attribute, such as factor X, is considered, each is scored as a percentage. All are multiplied as decimals and expressed as the cumulative percentage of that component. This convention is followed by all Storie index derivates.

The Qualitative Desert Land Potentiality Evaluation (Q_LDLPE) method was initially created in India to properly analyze desert soils, specifically in hyperarid, arid, and semi-dry desert ecosystems (Elwan, 2013; Elwan and Sivasamy, 2013b; Elwan, 2019). Score ratings for all criteria are determined using a variety of socioeconomic and political considerations on one side and soil attributes and environmental elements on the other. This method involves computing a potentiality index based on twenty-two elements of the indicated variety, each with a numerical weight and a score rating value. The criteria weights are decimal values graded between zero and one based on their influence on soil quality and health (Elwan and Sivasamy, 2013b). Criteria numerical rating values are provided in the standard guidelines of Elwan (2013) and Elwan (2019), with values ranging from 0 to 100 dependent on the type and degree of the limiting factor. Environmental considerations include topography, water availability, and natural hazards. Soil parameters include effective soil depth, soil texture, gravel on topsoil or inside subsoil, soil water retention, drainage and wetness, salt, soil response, gypsum, lime, fertility status, and soil color (Elwan, 2019). Furthermore, human resources, management, technology, infrastructure, and markets are all part of the socioeconomic state (Elwan and Sivasamy, 2013b). Nonetheless, the political entity that should be considered in the land evaluation by (Q_LDLPE) is related to decision-making authority, agricultural policy, and land ownership (Elwan, 2019).

Considering this, the study attempted to evaluate the cultivated desert soils and lands of the Al-Salheyia area, east of Delta, Egypt, using the nonspecialized and specialized land evaluation approaches for natural resource assessment of the desert ecosystem. The study's specific goal was to compare and test four well-known technical evaluation methodologies, correlate their results and performance, and make recommendations for improvement. The work also analyzes the shortcomings and inadequacies discovered in the Storie index, LCC, and FCC methodologies while evaluating Egyptian desert areas.

MATERIALS AND METHODS

Research Area Site

The studied area is the agricultural zone of the Al-Salheyia project for land reclamation, east of Delta, Egypt, with a land area of 41500 Faddans (≈17430 hectares) (Fig. 1). It is positioned between 30° 33' N - 30° 39' N latitudes and 31° 45' E - 32° 4' E longitudes (Fig.1). The location is in Egypt's historic deltaic plain semiarid desert ecosystem. This region is primarily planted with crops, vegetables, and fruits. The cultivated fruits were dominated by Valencia orange (*Citrus sinensis*), Grape (*Vitis spp*), and Mango (*Mangifera indica*). Al-Salheyia is located in Egypt's desert belt and has a short, rainy winter and a hot summer. According to climate information for the investigated area (Egyptian Meteorological Authority, 2022), summer temperatures range from 34 °C to 36 °C, with lower temperatures in

January reaching around 13 °C. The average rainfall is up to 24.8 mm, and the relative humidity is lower in the summer than in the winter, with the average humidity in the study region ranging between 45-56% from May to November. At the same time, the degree of evaporation is often more remarkable in the summer than in the winter. Wind speeds are frequently less than 9 meters per second, with an annual average of 4 meters per second (Egyptian Meteorological Authority, 2022).

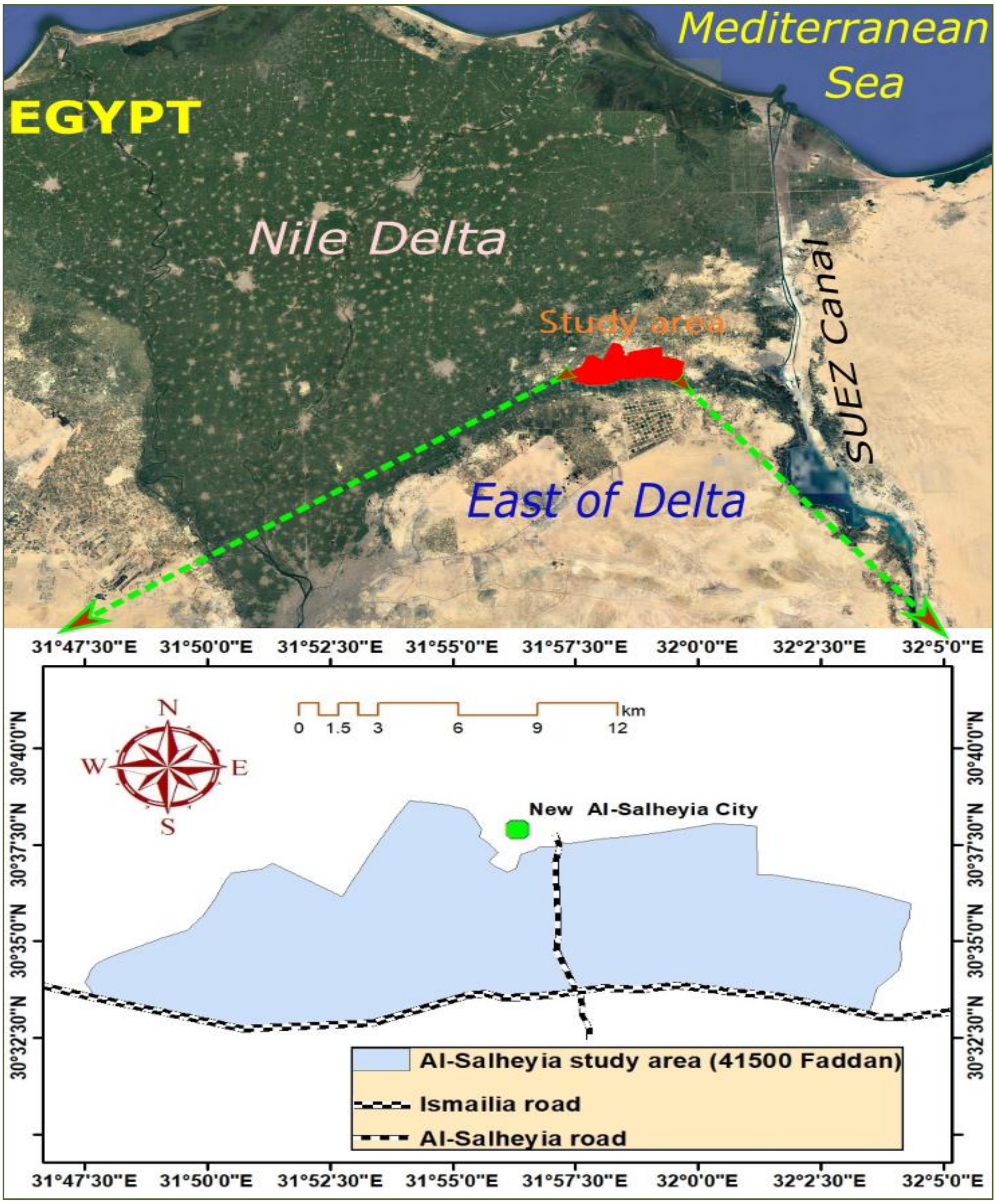

Fig. 1. Map showing the location of the Al-Salheyia study area.

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The principal sources of irrigation are good-quality surface water and groundwater, with surface water represented by the El-Ismailia and Al-Salheyia Canals with their tributaries (Fig. 2). The Quaternary groundwater aquifer is the primary source of groundwater in the studied area. Uncontrolled groundwater use causes significant drops in groundwater levels and changes in groundwater quality (Shata, 1965). The altitude of the research region ranges from 20 to 45 m above sea level (Shata and El Fayoumy, 1970), with a general slope to the north (Fig. 3). It is divided by a complicated irrigation system, which has a direct impact on both groundwater recharge and Quaternary aquifer movement (Awad and El Fakharany, 2020).

The study area is a part of the Al-Salheyia old deltaic plain, a natural extension of the Nile Delta (Fig. 3). This plain runs east of the Delta flood plain and west to the Suez Canal district (Shata, 1965). These lowlands are delimited to the south by the Anqabia-Ewaibid structural plain and the Gabel Mokattam-Ataqa structural plateau. El-Manzala Lake and the lacustrine plain in the north (Mabrouk *et al.*, 2016).

Stratigraphically, this area is mainly inhabited by Tertiary and Quaternary sedimentary chains (Said, 1981). The Eocene, Oligocene, Miocene, and Pliocene rocks belong to the Tertiary rocks. Quaternary deposits are found throughout the study area. They consist of ancient deltaic deposits consisting of coarse quartz sand, flint gravel, and occasional flint fragments with fossil wood remnants, as well as young Aeolian deposits consisting of fine to coarse quartz sands with noticeable variation in thickness (Fig. 4). Wadi sediments, alluvial fans, dunes, and Nile alluvium are examples of Quaternary sediments. Quaternary deposits are classified into two types based on their mode of development: Pleistocene and recent Holocene (Said, 1981). The principal aquifer in the research area is thought to be composed of Pleistocene deposits. It includes three types of deposits: ancient Aeolian sediments (Mit Ghamr Formation), ancient fluviomarine deposits, and ancient deltaic deposits (Shata, 1965). Holocene sediments are classified into two types: (i) young Neonile delta sediments (Bilqas Formation), consisting of Nile alluvium, fine sand, and clay (Fig. 4), and (ii) young aeolian sediments, consisting of fine to coarse loose sand with a thickness varying from 2 to 10 m (Mabrouk *et al.*, 2016).

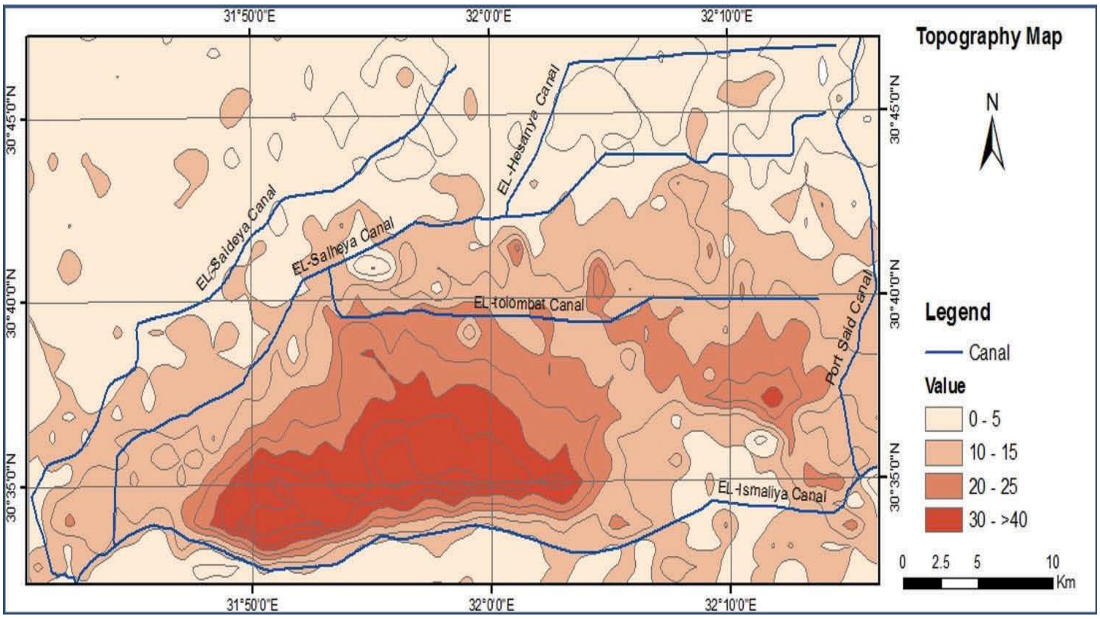


Fig. 2. The study region is depicted on a topographic map (Awad and El Fakharany, 2020)

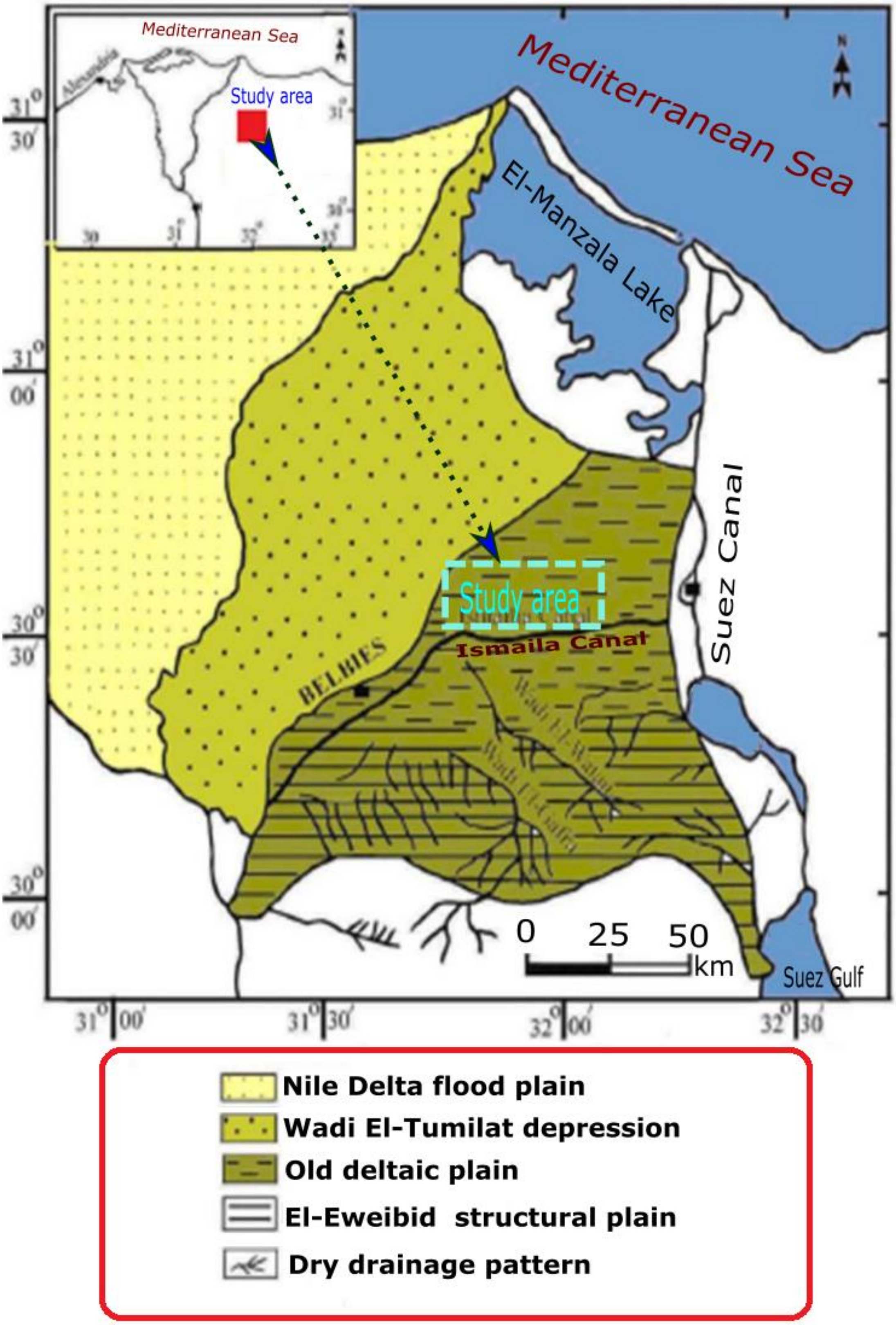


Fig. 3. Landforms of the Nile Delta east, including the Al-Salheyia study area.

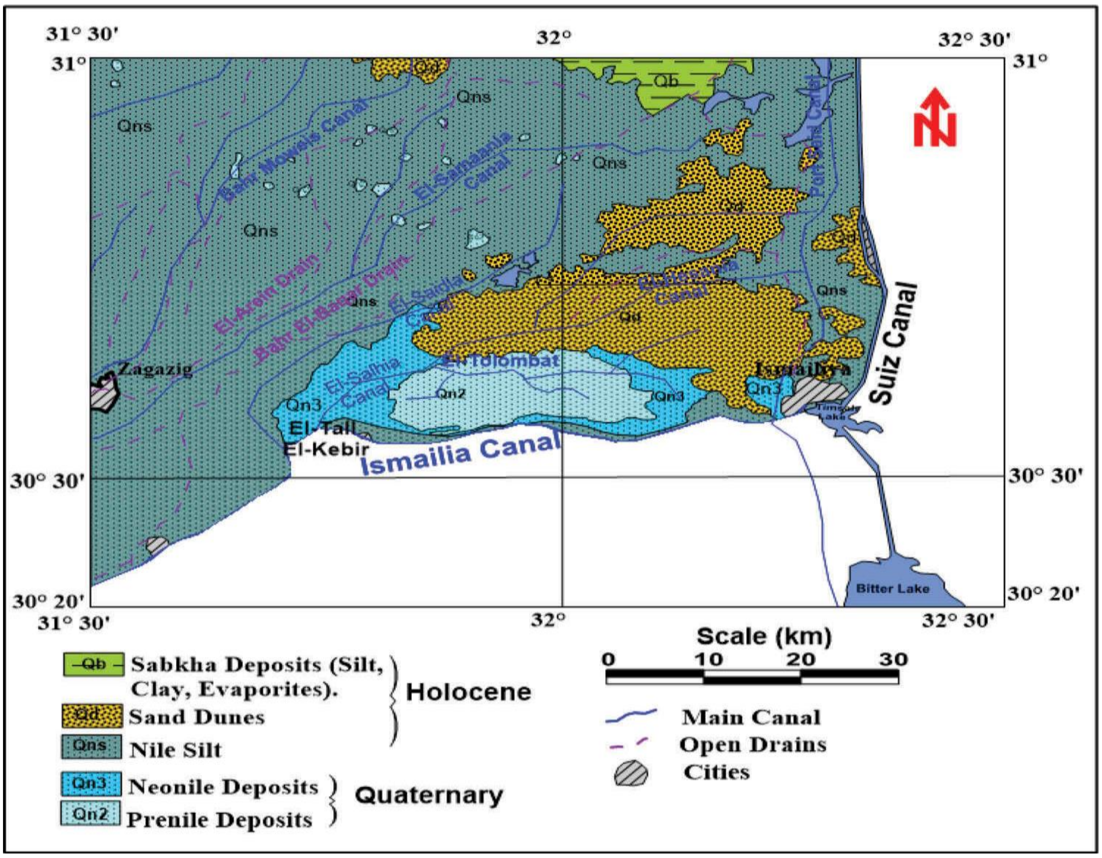


Fig. 4. Geological characteristics and aquifers in the study area (Awad and El Fakharany, 2020)

In the study area, the Quaternary aquifer is the most critical groundwater source for agriculture and drinking water (Fig. 4). The underground aquifer has unlimited forms to the southeast and is semi-limited to the northwest. The sediments of mixed gravel, sand, and shale are the main components of the Plio Pleistocene and compose the bottom portion of the Quaternary aquifer (Mabrouk *et al.*, 2016). Seepage from numerous aqueducts, such as open drains, freshwater canals, and excess irrigation water in agricultural lands, recharge the aquifer. The primary source of freshwater in the study area is Al-Salheyia Canal, sourced from Ismailia Canal. This fresh surface water irrigated different soil mapping units, particularly SMU1 and SMU2.

Fieldwork

The soil types in the research region are mapped using several transects and a free survey technique, with map units delineated primarily by crucial soil parameters such as depth, texture, salinity, and $CaCO_3$ content. Twenty-six pedon pits were utilized to characterize the soils of the study area (Figs. 5 & 6), and the pedon position was recorded using a portable GPS. The soil research of the Al-Salheyia region used a cross-sectional method from east to west, including all types of defined land utilization types (Fig. 5). The standard procedures of FAO (2006) were used for describing soil horizons and morphological properties such as thickness, texture, moist color, rock fragments, structure, consistency, presence of hard pans, and other pedogenic features. Samples were taken from studied soil pedons. The soil survey procedure is divided into three stages: the primary survey, the boundary of each mapping unit, and the spatial variation test. Based on the varied features of all soil pedons and auger pits, five soil mapping units (SMUs) were defined. However, just five reference pedons (one for each SMU) are used in the current study to indicate the main features of each map unit.

Laboratory Analyses

Physical, chemical, and fertility properties were investigated through air-dried and sieved soil samples. The hydrometer approach was used to determine soil texture (Gee and Bauder, 1986). Pressure plate equipment assessed gravimetric water, and available water content (AWC) was computed (Klute, 1986). Soil paste extract was used to assess electrical conductivity and soil pH (Soil Survey Staff, 2014). Nelson *et al.* (1990) updated the oxidation process for organic materials. The effective cation exchange capacity (ECEC) was evaluated by the standard procedures of Jackson (1973). The exchangeable sodium percentage (ESP) and $CaCO_3$ were calculated and determined using conventional procedures of Soil Survey Staff (2014). Artieda *et al.* (2006) were utilized to determine the gypsum concentration of the investigated soils. The FAO (1970) standard procedures for measuring available nitrogen were employed. The method of Soltanpour and Schwab (1977) was used to determine the available phosphorus and potassium concentrations. The standard methods of Lindsay and Norvell (1978) were used to determine available micronutrients (Fe, Mn, Zn, and Cu).

Crop Yield Observations of Land Utilization Types in the Study Area

Crop yield data for 2019-2022 were gathered from the Sharkia Governorate's Al-Salheyia initiative for land reclamation and agricultural development. Furthermore, through the exhibition of generated soil maps, extension workers, local farmers, and policymakers were educated on technology transfer among scientists and farmers to correctly identify land potentiality classes and crop patterns. The results of the suitability examination were shared with the farmers, who were matched based on observed crop production on their farm property, field observation, and current socioeconomic conditions. The plan's feasibility was discussed, including potential allocations to suggested crops, potential gains, and land sustainability. This resulted in the development of scientific interventions and technology transfer.

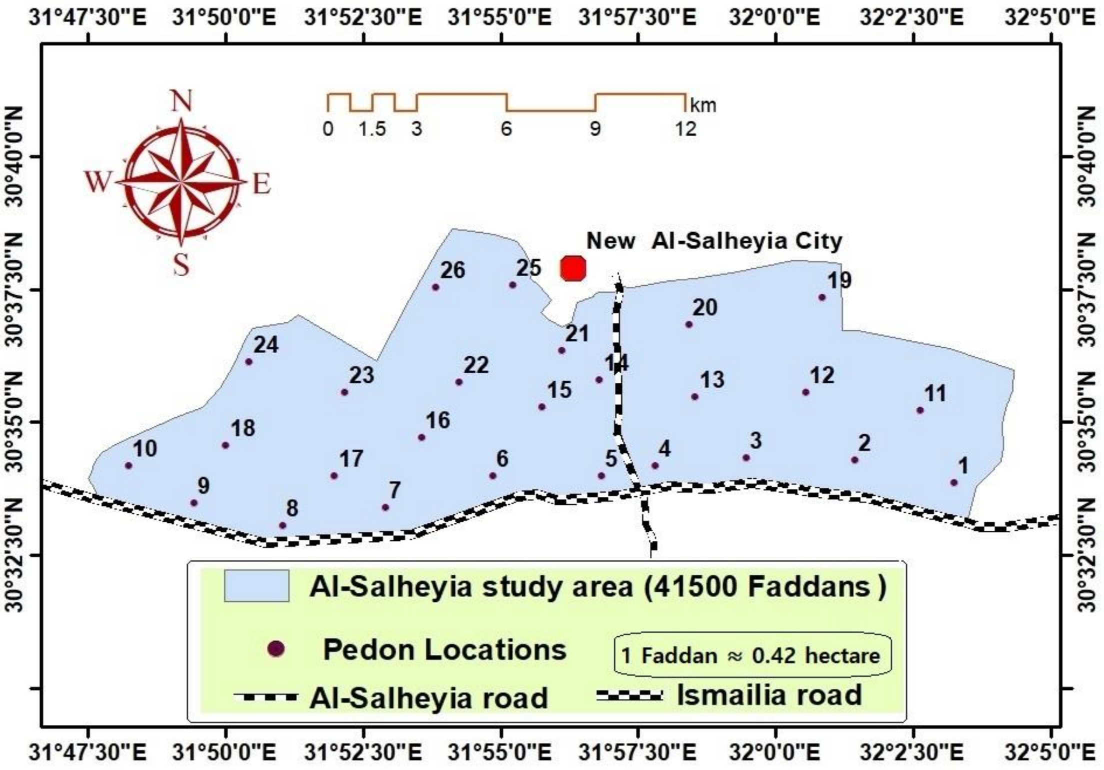


Fig. 5. Pedon locations on the cultivated lands of the Al-Salheyia study area.

Fig. 6. A broad excavation across the research area offers for pedon description activities.

Current land utilization types with different followed in the study area are shown in Fig. 7. Furthermore, a baseline survey of soil mapping units was conducted using a questionnaire to prepare for a comparison of tested land evaluation systems. This questionnaire included information on irrigation water quality, observed crop yields, agriculture inputs, current agricultural practices and management, livestock, fodder needs, infrastructure, implements, used machinery, and credit availability (Fig. 7; Table 1). Discussions at the local administrative unit level were also held to rank and prioritize soil characteristics and problems with proposed solutions. Following that, group talks with additional farmers were held to confirm the group's findings and decisions. Crop growth and production expectations were monitored and documented for each soil mapping unit after workshops among professionals, farmers, and policymakers (Table 1).

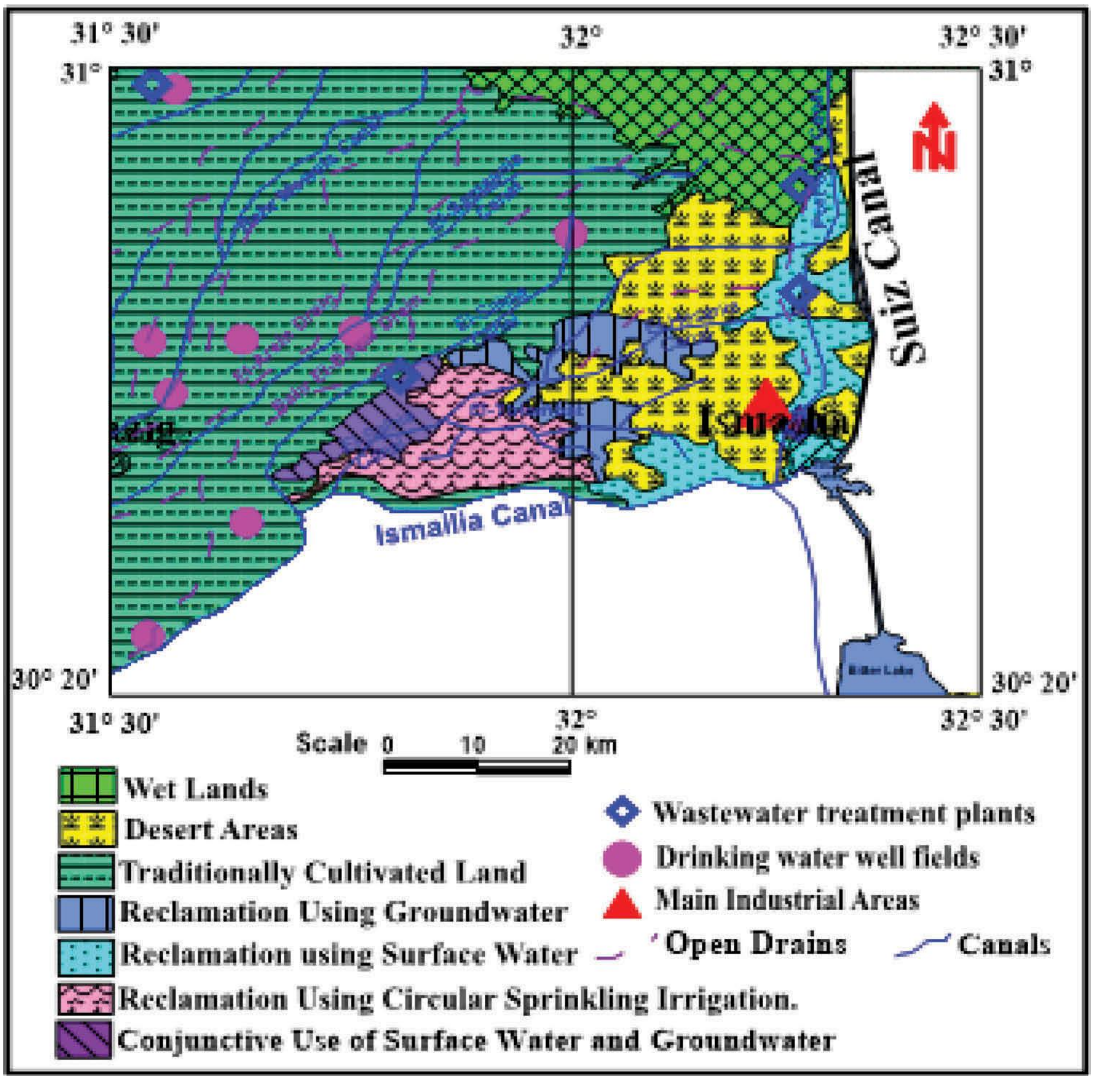


Fig. 7. Land uses and irrigation systems followed in the Al-Salheyia project for land reclamation.

Table (1): Field observation for cultivated crops across land utilization types of the study area.

S.M.U.	Cultivated products	Observed crop growth	Expected crop yield and production	Irrigation system
SMU1	Grapes as dominant	Healthy (90-100%)	80-90 %	Circular sprinkling irrigation is a dominant
SMU2	Mixed fruits	Healthy (80-90%)	70-90%	
SMU3	Vegetables	Healthy (60-70%)	55-65%	Drip irrigation is a dominant
SMU4	Field crops	Healthy (75-85%)	60-70%	
SMU5	Vegetables, rice	Healthy (<50%)	<60%	Surface irrigation only

Tested Land Evaluation Methods

One of the systems used for this study was the USDA land capability classification (LCC) (Klingebiel and Montgomery, 1961). Quandt *et al.* (2020) adopted the modified form (Table 2). The LCC uses only physical terrain attributes to allocate land in eight arable and nonarable classes. According to Thomas (2010), five indicators were the most important soil properties. They are permeability and infiltration of topsoil and subsoil, effective soil depth, erosion risks, surface soil texture, and slope. Quandt *et al.* (2020) included waterlogging, growing period length, and stoniness and rockiness (Table 2). These were used to classify lands ranging from class I to class VIII. The first four classes (classes I to IV) were for arable land, and the second (classes V to VIII) were for nonarable lands. The most limiting element decided which class a soil belonged to. Table 2 lists the physical criteria and their respective score ratings.

Modified forms of Sanchez *et al.* (2003) for fertility capability classification (FCC) have been revised and adopted for further soil examination. The system divides soils into homogeneous physicochemical and fertility groups. Type, substrata type, and condition modifiers are the main components and levels of FCC Type indicates topsoil texture and substrata type refers to subsoil texture. Condition modifiers indicate the limitations and soil qualities that harm crop performance. FCC units are defined by letter combinations that denote factors. Specific soil qualities as modifiers utilized as criterion included soil texture, $CaCO_3$ (b), soil salinity (s), cracking (v), low OM (m), low ECEC (e), dry season (d), soil pH, and so on.

The Storie index is a mechanism for determining land's potential utilization and productive capacity based on a few soil properties and slope (Storie, 1978). The judgments are highly subjective and necessarily based on an evaluation technique system developed for specific California irrigated soils. O'Geen *et al.* (2008) developed a revised version based on the digital ratings given by USDA Natural Resources Conservation Services (NRCS). The Storie index was computed as follows:

$$\text{Storie index} = \left[\left(\frac{\text{Factor A}}{100}\right) \times \left(\frac{\text{Factor B}}{100}\right) \times \left(\frac{\text{Factor C}}{100}\right) \times \frac{\text{Factor X}}{100}\right] \times 100$$

Where factor A represents the degree of soil pedon growth, factor B represents surface soil texture (Table 3), factor C represents slope, and factor X represents chemical and fertility subfactors (ECe, S.A.R., pH), as well as hydrology and physical subfactors (drainage, wetness, flooding, and erosion). The Storie index gives six soil grades for land categorization: excellent, good, fair, poor, very poor, and nonagricultural land. The soil texture was evaluated using silt and clay percentages, with the average value used to determine the texture rating. The ideal loam texture parameters for agricultural production were determined to be 50% silt and 30% clay.

Table (2): The parameter ratings utilized in USDA land capability categorization.

Indicator	Class							
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Slope(%)	0-2	2-8	8-15	15-30	30-40	40-50	50-60	>60
Solum depth(cm)	>150	100-150		50-100	25-50	<25		
Erosion	None	Slight	Slight to moderate		Moderate		Severe	Very severe
Topsoil texture	CL-SL-L	L-SiL-CL-SL	L-SL-CL-SiC-HC	SL-L-SiL-CL-SiC-C-HC			S-SL-L- SiL-CL-SiC-C-HC	
Waterlogging	None		Intermittently waterlogged		Regularly waterlogged		Waterlogged-swamps	
Infiltration	Good	Good	Moderate	Moderate to poor		Poor	Very poor	
Surface stoniness (%)	None	Slightly stony		Moderately stony		Stony	Very stony, rock outcrops	
L(loam), SL (sandy loam), CL(clay loam), SiL(silt loam), SiC(silty clay), HC(heavy clay), C(clay).								
Source: Quandt *et al.* (2020).								

Table (3). The factor B rating score of surface textural class for calculating the Storie index.

Surface textural class (Factor B)	Score rating
SiL (silt loam), L (loam), Si (silt), FSL (fine sandy loam), VFSL (very fine sandy loam),	100
LVFS (Loamy very fine sand), SL (sandy loam), SCL (sandy clay loam), Calcareous SiCL, CL (clay loam)	95
COSL (coarse sandy loam), LFS(loamy fine sand), noncalcareous SiCL	90
LS (loamy sand),VFS (very fine sand)	80
FS (fine sand), LCOS (loamy coarse sand), SC (sandy clay)	65
S (sand), SiC (silty clay)	60
C (clay)	50
COS (coarse sand)	**30**

Source: Storie (1978) and O'Geen *et al.* (2008).

The Q_LDLPE model considers the intricacies of soil, ecological, and socioeconomic factors that determine land use type and political concerns (Table 4) that enable plan execution (Elwan, 2019). The calculating analysis of Q_LDLPE models includes a ranking order of the criteria weights and assessment ratings. The land or soil's ultimate potentiality index is determined by multiplying the criterion percentage by the rating score for each criterion. The total of all criterion percentages is then calculated for Q_LDLPE as follows:

$$Q_L\text{DLPE} = \{(R1\times W1) + (R2\times W2) + (R3\times W3) + (R4\times W4) + (R5\times W5) + (R6\times W6) + (Rn\times Wn)\ldots..\}$$

Where R1, R2, R3, R4, R5, R6, and Rn are the rating scores of indicators 1, 2, 3, 4, 5, 6, and n in the evaluation ratings of Elwan (2013; 2019); n represents the following criterion. W is the weighted average of the twenty-two indicators in Table (4). The resulting Q_LDLPE index categorizes lands as follows: (i) high potential land (81-100%); (ii) moderate potential land (66-80%); (iii) slight potential land (46-65%); (vi) low potential land (26-45%); and (v) non-potential land (25%).

Statistical Analyses for Evaluation Methods Comparison

The soil ratings were connected using Spearman's rho model at the 0.01 significance level. The kappa statistical analysis was used to determine technique agreement. The kappa coefficient (k) was used to compare the agreement of tested land evaluation methodologies (Vasu *et al.*, 2018). The computation is based on the difference between how much agreement occurs and how much agreement would be expected to exist by chance alone. The kappa coefficient was calculated using the formula below (Vasu *et al.*, 2018):

$$\mathbf{k} = \frac{P(A) - P(E)}{1 - P(E)}$$

Where k represents the kappa coefficient, P(A) represents the percentage of times the coders agree, and P(E) represents the percentage of times they would agree by chance. A kappa value less than zero denotes no agreement; k: zero denotes poor agreement; k: zero-0.2 denotes slight agreement; k:0.21-0.40 denotes fair agreement; k:0.41-0.60 denotes moderate agreement; k:0.61-0.80 denotes substantial agreement; and k:0.81-1.0 denotes perfect agreement (Landis and Koch, 1977).

Table (4): Overview of the Q_LDLPE evaluation model showing land criteria type and criteria weight.

Land criteria type	Land criteria weight scores
	Q_LDLPE model
A) Environment	
1) Water availability	0.20
2) Topography	0.10
3) Natural hazards (Flooding)	0.05
B) Soil pedon	
4) Effective soil depth	0.10
5) Coarse fragments	0.05
6) Soil texture	0.04
7) Soil water retention	0.03
8) Soil drainage	0.03
9) Soil reaction (pH)	0.03
10) $CaCO_3$ (%)	0.03
11) Soil salinity (EC.)	0.03
12) Gypsum content	0.02
13) Fertility status	0.02
14) Soil matrix color	0.02
C) Socioeconomic measures	
15) Infrastructure	0.06
16) Labors	0.03
17) Technologies	0.02
- Soil enhancement	--
- Water management	--
- Crop improvement	--
18) Human management	0.02
19) Markets	0.02
- Food demand	--
- Input prices	--
D) Political entity	
20) Decision making	0.04
21) Agricultural policies	0.03
22) Land tenure	0.03
Sum criteria weight	**1.00**
Source: Elwan (2019).	

RESULTS AND DISCUSSION

Soil Characterization of Al-Salheyia Area

Table 5 shows the morphological characteristics of the reference pedons, while Table 6 shows their physiochemical values. Fig. 8 depicts the reference pedons of each soil mapping unit. Additionally, Fig. 9 depicts soil mapping units with their properties summarized. A horizon sequence of Ap-BC-Ck-C categorized pedons of SMU1 without any root zone limitations vertically within pedon layers. In contrast, representative pedons of SMU2, SMU3, SMU4, and SMU5 were characterized by horizon sequence of Ap-Bw-C, Ap-Btk-Btzm-Btx, Ap-Bw-BC-Cr, and A-Btzg-Btgx-W, respectively, with the presence of root-restrictive layer at different depths within studied soil pedons. The morphological characteristics of

Table 5. Certain pedomorphological and physical features of the reference pedons across cultivated soil mapping units of the study area.

SMU	Pedons ID.	Horizon suffix[1] and depth, cm	Drainage class[2]	Slope gradient	Erosion	Soil structure[3]	Soil consistence[4]	Textural class[5]	Rock fragments	Permeability	Root-limiting layer[6]
SMU1	5,6,7,8,15, 16,17,22	Ap (0-20)	SE	04 (Very gently sloping; 1.0–2.0%)	Slight	GRR	L,SO-PO	COS	3.05	Very rapid	--
		BC (20-60)				SBK	S,SS-SP	SL	1.65		--
		Ck(60-105)				MA	SH,SO-PO	COS	0.35		--
		C (105-155)				MA	SH,SS-SP	LVFS	4.03		--
SMU2	14, 19, 20 &21	Ap (0-30)	WD	01 (flat; 0–0.2%)	None	SG	SH,SO-PO	COS	2.15	Rapid	--
		BW (30-85)				GR	SH,SS-SP	FSL	0.65		--
		Cz (85-140				MA	MH,SO-PO	LCOS	1.77		SA
SMU3	23, 24, 25 & 26	Ap (0-35)	SP	03 (Nearly level; 0.5–1.0%)	None	SBK	FI, SS-MP	SC	4.32	Slow	--
		Btk (35-70)				ABK	VFI, MS-MP	SiC	1.36		PE
		Btzm (70-95)				PR	SR, ST, MS-MP	SC	0.65		CH, SA
		Btx (95-135)				COL	EF,VS-VP	C	0.0		FR
SMU4	1, 2, 3, 4, 5, 11, 12 & 13	Ap (0-15)	SP	04 (Very gently sloping; 1.0–2.0%)	Slight	MA	SHL,SO-PO	VFSL	7.15	Moderate	--
		Bw (15-35)				ABK	MH, S,SS-SP	Si	6.32		--
		BC (35-55)				SGR	H,SO-PO	L	2.05		--
		Cr (55-85)				MA	EF, M, SS-MP	SL	17.36		CH
SMU5	9, 10 & 18	A (0-20)	VP	02 (level; 0.2–0.5%)	None	ABK	FI, MS-VP	SiC	1.05	Very Slow	--
		Btzg (20-50)				COL	FI, VS-VP	C	2.31		SA
		Btgx (50-80)				SBK	VFI, VS-VP	C	0.65		FR
		W (80+)	High water table			--	--	--	--		

Explanations: [1]**Horizon designation suffixes** were abbreviated based on the USDA Soil Taxonomy of Soil Survey Staff (2022); [2]**Drainage:** SE:somewhat excessively drained; WD:well drained; MW: moderately well drained; SP: somewhat poorly drained;VP:very poorly drained; [3]**Soil structure:** GR: granular, ABK: angular blocky, SBK:subangular blocky, PR:prismatic, COL: columnar, SGR: single grain, MA: massive, [4]**Soil consistence; Dry:** L:loose, S:soft, MH:moderately hard, HA:hard, VH:very hard, EH:extremely hard, **Moist**: FI:Firm, VFI:Very Firm, EF:extremely firm, SR: slightly rigid; ST:strongly cemented, M:moderately cemented, **Wet: Stickiness**: SO:nonsticky, SS:slightly sticky, MS:moderately sticky,VS:very sticky, **Plasticity**:PO:nonplastic, SP:slightly plastic, MP: moderately plastic, VP:very plastic; [5]**Soil texture:** COS:Coarse sand, LCOS:loamy coarse sand, LVFS:loamy very fine sand,SL:sandy loam,FSL:fine sandy loam, VFSL:very fine sandy loam; L: loam, Si:silt, SiC: silty clay,SC: sandy clay, C:clay; [6]**Root-limiting layer (Restriction):**CH:Cemented horizon, SA:Salinity hazard, PE:Petrocalcic, FR: Fragipan.

SMU3 and SMU5 suggested a significant buildup of illuvial clay within specific soil horizons of investigated pedons (Btk, Btk, Btzm, Btx, Btzg, and Btgx) (Table 3). The SMU1 unit is primarily an old deltaic plain with a slope gradient of flat (0-0.2%). The parent material of the soils differs depending on whether they are recent or subrecent alluvium. SMU1 has an area of 10250 Faddans (24.7% of the total area), whereas SMU2, SMU3, SMU4, and SMU5 have areas of 6500 Faddans (15.7%), 12700 Faddans (30.6%), 5900 Faddans (14.2%), and 6150 Faddans (14.8%), respectively.

Topsoil textures varied between coarse sand of SMU1 and SMU2 to silty clay of SMU5 pedons, with fine sandy loam to clay at subsoil horizons. Topsoil moist color was primarily very pale brown (10YR 8/2; 8/3) and yellow (10YR 7/6) for SMU1, SMU2, and SMU4, and varying from very dark grey (10YR 3/1) for to black (10YR 2/1) for SMU3 and SMU5. The physicochemical and fertility parameters of the examined SMUs were as follows: pH ranges from 7.32 to 9.11; EC_e from 0.84 (nonsaline) to 31.02 d Sm^{-1} (strongly saline); $CaCO_3$ from 3.65 (moderately calcareous) to 24.85% (strongly calcareous); gypsum from 0.32 to 4.65% (slightly gypsiric); ECEC from 2.17-41.25 cmol/kg; OM from 0.01 to 0.51; available N from 5.03 to 67.32 ppm; available P from 3.04 to 14.3 ppm; available k from 4.65 to 176.1; as well as micronutrients of Cu (0.01-0.85 ppm), Mn (0.32-2.01 ppm), Fe (0.14-5.01 ppm), and Zn (0.02-1.32 ppm) (Table 6).

As a result of the increased water Table, waterlogging was discovered in SMU5 within the soil pedons levels (Fig. 8). As a result, several specialists are investigating issues related to shallow groundwater levels and land reclamation methods that create soil salinity owing to waterlogging (Mahmoud, 2017). Agricultural reclamation in the expanded desert borders and waterlogging zones has a good correlation, according to Kaiser *et al.* (2013). The influence also causes direct losses in agricultural productivity and income, significantly impacting farmers (Table 1) (El-Nashar, 2013). Installing drainage systems may help alleviate waterlogging (Mahmoud, 2017). A suitable drainage system should be created in waterlogged areas, such as the SMU5 area, to dewater the excess irrigation water and protect the old cultivated land from deterioration.

Land Evaluation Methods Results

Table 7 displays the results of land evaluation classes as per L.C.C., Storie index, FCC, and Q_LDLPE methodologies. According to the USDA LCC system, arable land soils vary from class III to IV, with coarse soil texture (sand) and arid climate being the primary constraints. These arable lands cover 35350 Faddans (85.2% of the total area). The other lands of SMU5 were all classified into nonarable class–V, with severe limitations being sandiness, rapid permeability, and waterlogging (wetness), which are also root zone limitations (Figs. 8 & 10). According to the USDA LCC, most of the investigated region lands have severe restrictions that prevent decision-makers and planners from using these resources for agricultural development. The primary limits identified in SMU5 were heavy clay texture of Bt horizons, fragipan, and cemented horizons, moderate fertility status, moderate to strong salinity or sodium, dry environment, very slow permeability, and wetness of waterlogging. Therefore, an area of 6150 Faddans has been placed under the nonarable category (class-V) (Table 7). The sandy texture, poor fertility, and arid climatic components were also given very low evaluation ratings, and hence, the sandy SMUs (SMU1 and SMU2) were positioned in lower arable classes.

According to LCC methodologies, soils of class V have more restrictions than soils in classes III and IV when used for cultivated crops, and conservation practices are typically more challenging to implement (Table 7). They can be utilized for farmed crops, range, woodland, and wildlife food. Soil constraints in class V limit the quantity of clean cultivation, time of planting, tillage, crop selection, harvesting, or some combination of these limits.

Storie index grading classified the investigated lands into four soil grades (Fig. 11). Only SMU4 was placed in fair soil grade (Storie index: 40-59%). Due to the dominant course soil texture, soils of SMU1 were placed in poor grades (Storie index: 20-39%), and soils of SMU2 have Storie index values of 10-19%, indicating very poor soils.

Table 6. Important soil physicochemical and nutrient properties for studied pedons

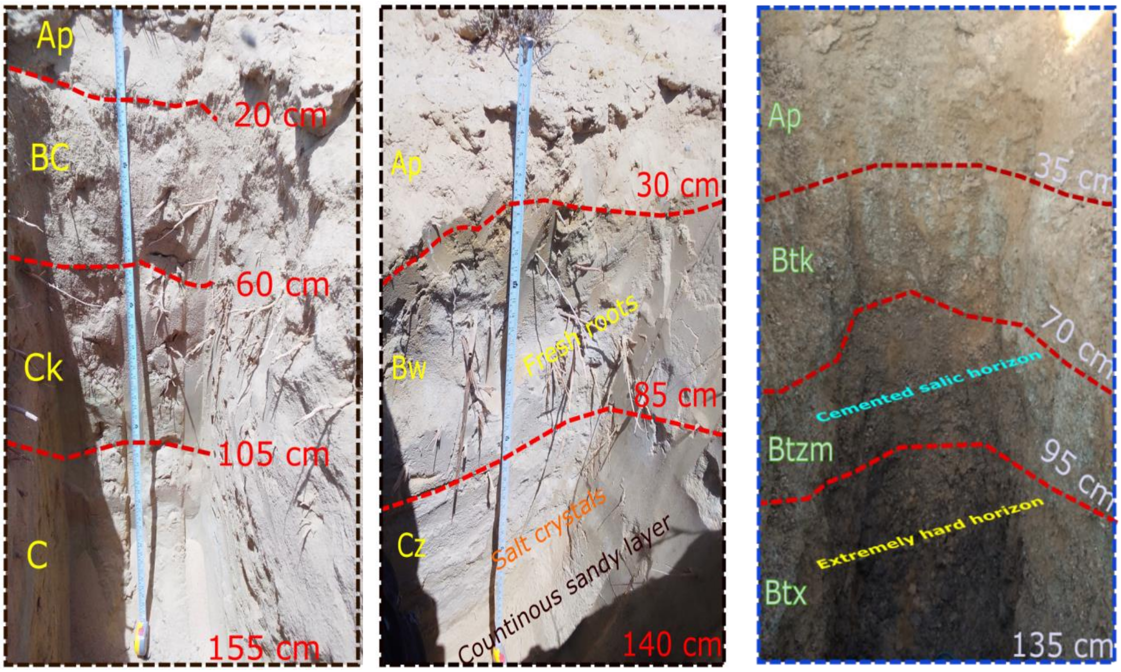
SMU	Horizon	Physico-chemical characteristics								Available macro and micronutrients (ppm)						
		AW (%)	pH	EC_e (dS m^{-1})	ESP (%)	$CaCO_3$ (%)	Gypsum (%)	ECEC cmol/kg	OM (%)	N	P	K	Fe	Mn	Zn	Cu
SMU1	Ap	4.25	7.85	0.84	6.05	3.65	0.36	2.17	0.12	15.32	6.32	32.5	1.35	0.95	0.47	0.09
	BC	7.05	7.32	1.06	5.23	7.26	1.05	5.10	0.04	17.03	4.25	45.32	1.05	0.65	0.24	0.14
	Ck	5.14	8.01	0.95	5.18	9.78	0.32	3.65	0.09	20.14	5.01	36.15	2.65	1.04	0.31	0.07
	C	6.35	8.42	1.33	5.46	5.35	2.35	4.65	0.15	5.99	7.01	4.65	0.98	1.13	0.12	0.01
SMU2	Ap	4.98	8.77	10.24	4.66	10.25	1.05	2.99	0.08	11.02	5.58	22.32	2.35	1.20	0.34	0.34
	Bw	7.62	8.65	8.99	5.54	11.35	4.03	4.13	0.03	17.03	4.26	55.45	1.07	0.57	0.02	0.24
	Cz	6.84	8.02	16.45	4.84	15.62	2.24	3.78	0.01	5.03	3.04	45.01	0.98	0.32	0.34	0.16
SMU3	Ap	29.35	8.14	11.20	6.43	7.15	4.32	21.57	0.24	18.62	13.05	120.3	3.15	1.63	0.98	0.85
	Btk	38.32	7.98	7.54	5.11	9.99	1.27	25.32	0.31	29.30	14.30	154.7	4.01	1.81	1.01	0.24
	Btzm	33.15	8.56	15.98	9.25	8.24	3.62	33.65	0.14	11.05	10.24	136.5	3.06	1.25	1.3	0.35
	Btx	42.35	8.98	13.62	5.19	9.36	4.05	41.25	0.10	18.62	8.62	147.2	2.98	1.45	1.08	0.07
SMU4	Ap	7.23	8.54	7.23	4.97	15.62	2.69	11.74	0.21	22.02	7.06	111.2	0.29	1.25	0.98	0.31
	Bw	13.25	9.11	5.06	9.32	20.32	4.32	15.36	0.18	21.3	8.02	98.62	0.32	1.10	0.57	0.07
	BC	9.05	8.69	4.88	8.13	19.35	1.98	13.15	0.16	19.65	5.14	45.01	0.14	1.35	0.62	0.21
	Cr	8.62	8.44	6.35	6.25	24.85	4.05	10.32	0.05	17.45	3.32	23.01	0.34	0.65	0.14	0.31
SMU5	A	37.32	8.32	27.62	11.32	11.25	2.04	31.15	0.51	51.2	11.05	155.3	5.01	2.01	1.32	0.59
	Btzg	45.62	8.99	31.02	17.06	15.32	4.65	39.45	0.24	45.06	14.06	176.1	3.62	1.35	1.04	0.38
	Btgx	49.35	8.47	19.75	10.65	13.36	0.32	35.35	0.32	67.32	13.01	165.9	4.65	1.24	0.98	0.24
	W	**High water table**								--	--	--	--	--	--	--

AW (soil available water) ; ECEC (effective cation exchange capacity expressed in cmol (p^+) kg^{-1} soil); ESP (exchangeable sodium percentage); OM (organic matter).

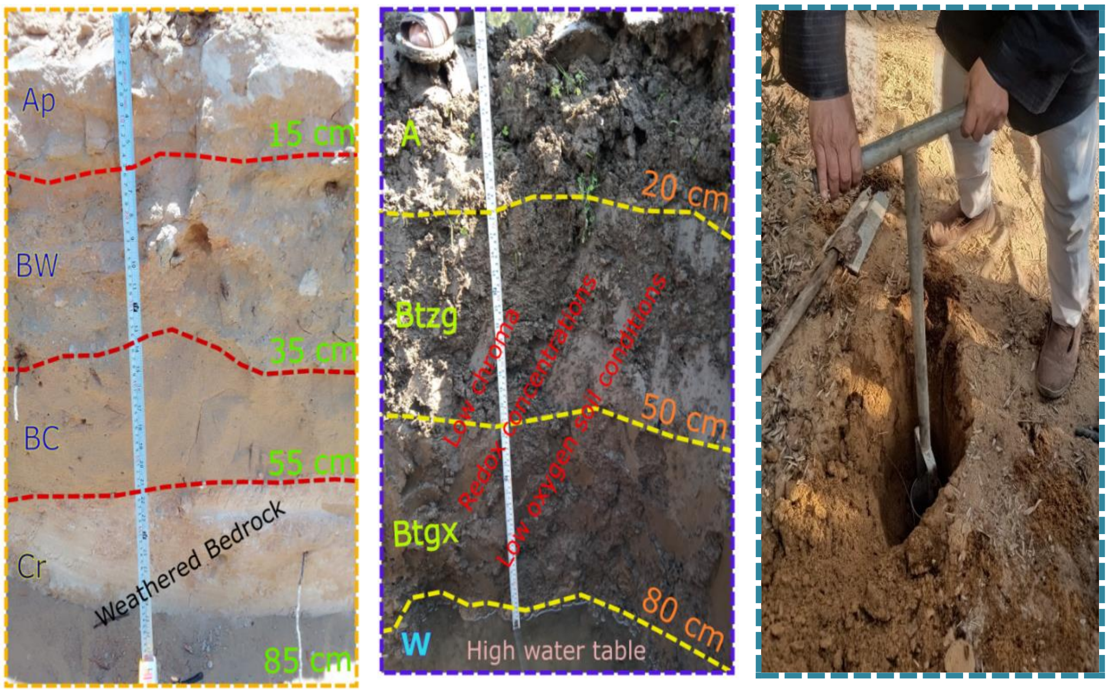
Table 7. Interpretative groupings of the lands of Al-Salheyia area under investigation

SMU	USDA LCC System		Storie Index		FCC Method		Q_LDLPE model	
	Class and Subclass*	Area (Fad.; %)	Soil Grade	Area (Fad.; %)	Type/substrate type and Modifiers**	Area (Fad.; %)	Potentiality Class	Area (Fad.; %)
SMU1	Class-IV s,c	29450 Fad.; 71%	Grade 4: Poor	10250; 24.7%	S e,d,m	10250; 24.7%	High potential lands	16750; 40.4%
SMU2			Grade 5: V. poor	6500; 15.7%	S e,s,b,d,m	6500; 15.7%		
SMU3			Grade 6: Nonagricultural	12700; 30.6%	C s,b	12700; 30.6%	Moderate potential lands	18600; 44.8%
SMU4	Class-III s,c	5900 Fad.; 14.2%	Grade 3: Fair	5900; 14.2%	L e,d,m	5900; 14.2%		
SMU5	Class-V w,s,c	6150 Fad.; 14.8%	Grade 6: Nonagricultural	6150; 14.8%	C g^+,s,b,v	6150; 14.8%	Slight potential lands	6150; 14.8%

Fad. (Faddans); 1 Faddan ≈ 0.42 hectare; *: W (wetness & waterlogging); S (soil permeability & soil texture); c (arid climate conditions). **: S e,d,m: Sandy soils having very severe limitations of low ECEC(e), dry season (d), and low OM (m); S e,d,m: sandy soils having limitations of low ECEC, dry season, and low OM, respectively; C s,b: Clayey soils with limitation related to soil salinity (s) and high $CaCO_3$; L e,d,m: Loamy soils with limitations of low ECEC (e), dry season (d), and low OM (m); C g+,s,b,v: clayey soils having severe limitations related to waterlogging (g+), high salinity (s), high $CaCO_3$ (b), vertic properties (v).



Soils of SMU1 **Soils of SMU2** **Soils of SMU3**



Soils of SMU4 **Soils of SMU5** **In the study area, an auger was used to test the boundaries of the soil mapping units.**

Fig. 8. Soil pedons of Al-Salheyia study area

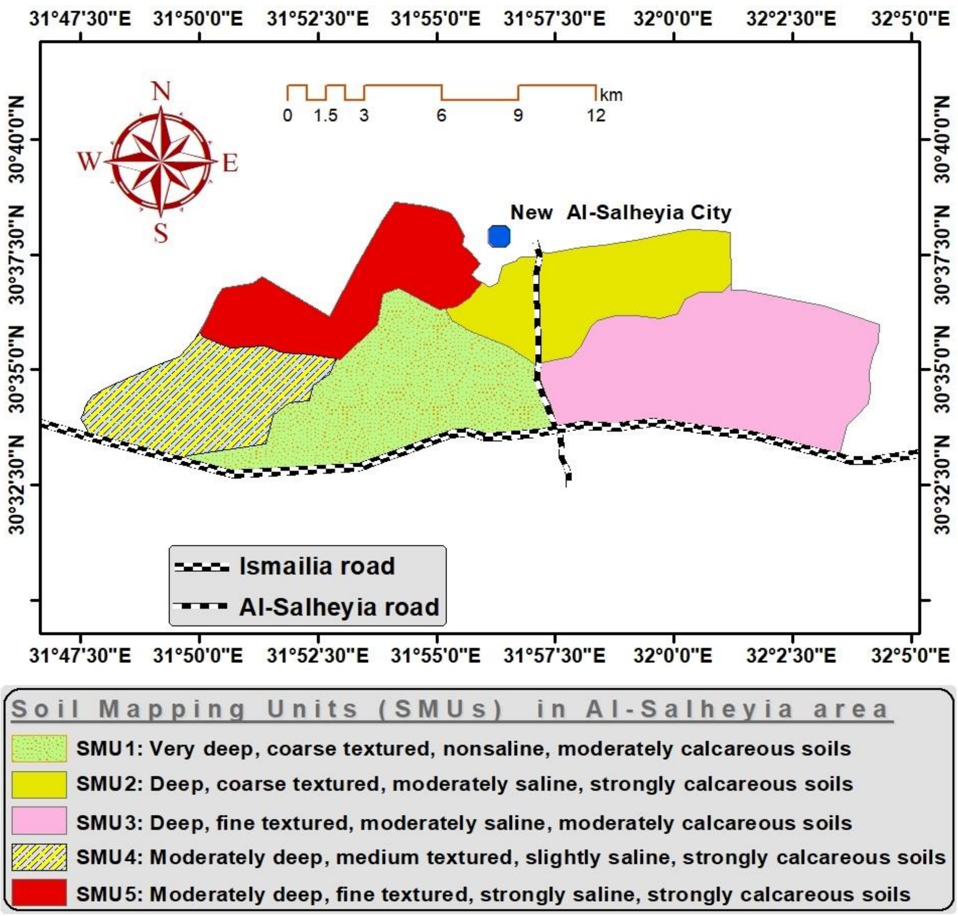


Fig. 9. Soil mapping units of the study area depending on the significant soil characteristics.

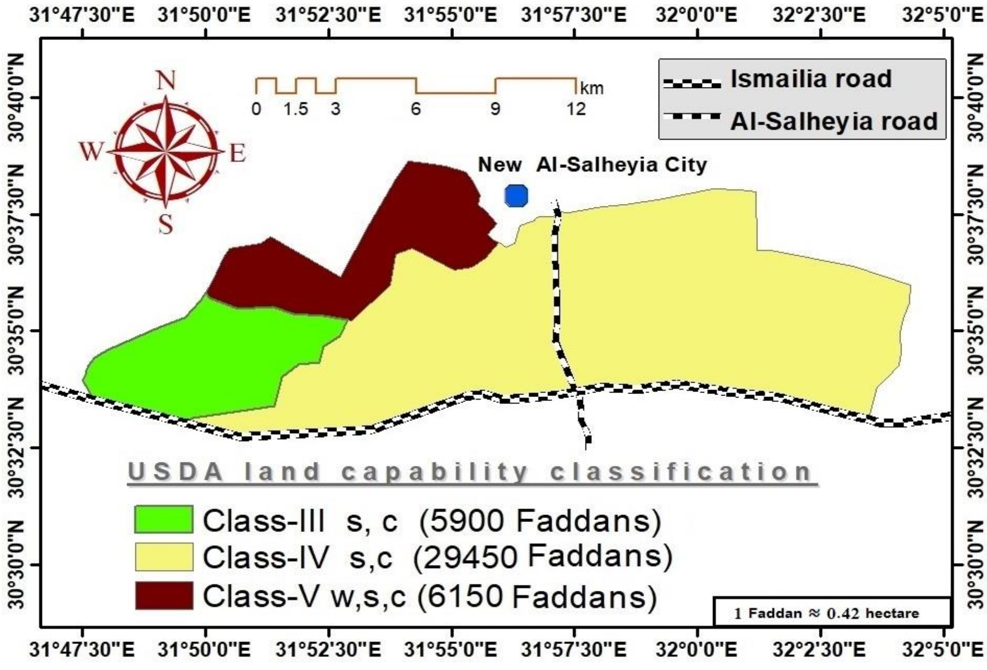


Fig. 10. The land capability classification of the study area using the USDA LCC method.

Meanwhile, 18850 Faddans of SMU3 and SMU5 were classified as nonagricultural soils (Storie index 10%) due to rooting-zone constraints due to cemented horizons or fragipan and waterlogging conditions (Table 7; Fig. 11). It is worth noting that, despite having high scores for high degree of soil profile development (depths 80->100 cm), slope, and surface soil texture in SMU3 and SMU5, multiplication of these factor scores resulted in nonagricultural classes (Table 7). SMU1 and SMU2 soils were classified as poor and very poor classes (grades 4 and 5), respectively (Fig. 11). These soils received the highest scores for factors A, C, and X but received the lowest score for component B, which is 0.3 for coarse sand of surface layers (Table 3), which resulted in these soils being classified as lower arable classes unfairly. SMU4 soils provide fair (grade 3) agricultural productivity. However, they have lesser soil characteristics than SMU1 and SMU2 (Table 7).

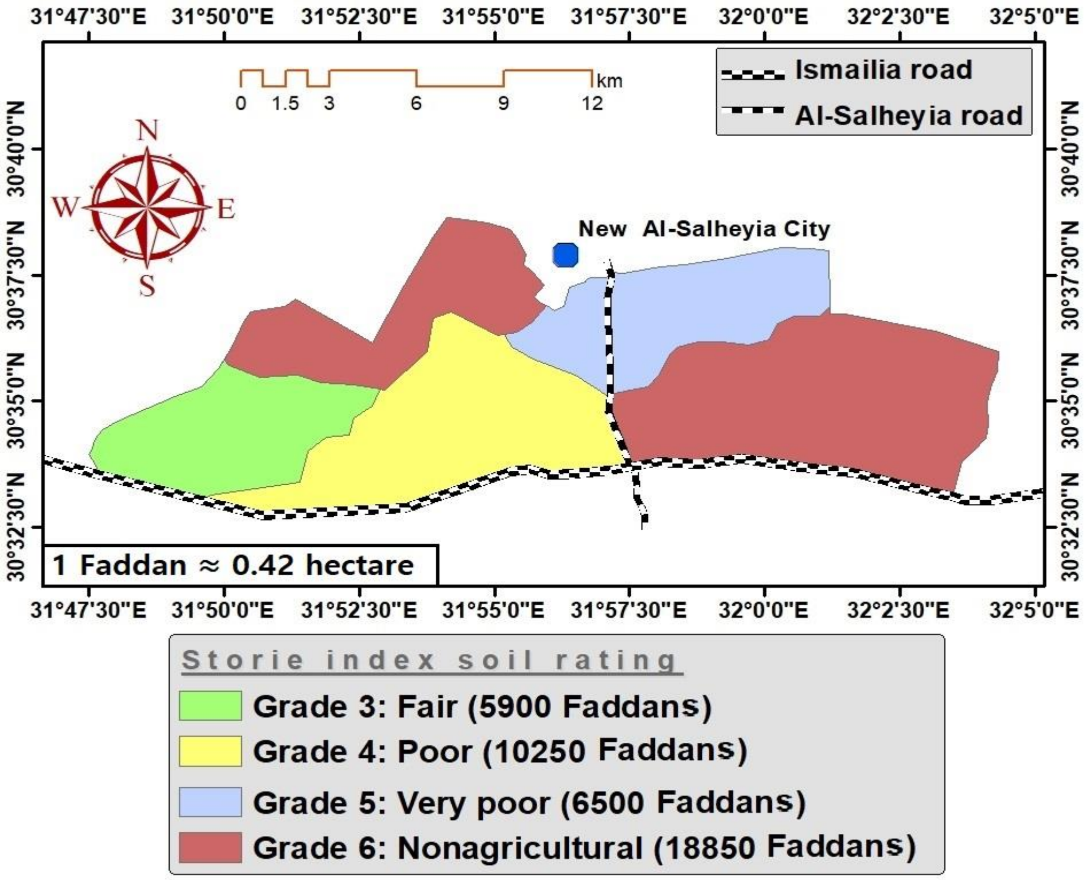


Fig. 11. Soil ratings of the study area using the Storie index.

The FCC results are reported in Table 7 and illustrated in Fig. 12. The soil textures on the topsoil and within the subsurface horizons are reflected by this method. The soils investigated were discovered to be sand, loam, or clay. According to FCC, type S (sand) has a poor water-holding capacity and a high rate of infiltration; type L (loam) has an excellent water-holding capacity and a medium rate of infiltration; and type C (clay) has a good water-holding capacity but a low rate of infiltration. Excess waterlogging (g+), low ECEC (e), low organic matter (m), high $CaCO_3$ (b), high salinity (s), cracking and vertic condition (v), and dry climate (d) were indicated as modifiers as constraints for soil quality in the study region by the FCC. The soil reaction (pH) of most horizons of SMU3, SMU5, and SMU5 was strongly alkaline (>8.5), with the limiting modifier (b) indicating excessive $CaCO_3$, which resulted in p-fixation and limited micronutrient availability. The modifier 'g+' was detected only in SMU5 soils, indicating waterlogging and NO_3 denitrification due to anaerobic conditions within the soil horizons of SMU5. However, this SMU5 situation is favorable for rice cultivation. Except for SMU3 and SMU5, all other pedons had an 'e' modifier, necessitating the best use of organic manures and chemical fertilizers. The following FCC types and modifiers were found in the research area: S e,d,m for SMU1; S e,s,b,d,m for SMU2; C s,b for SMU3; L e,d,m for SMU4; and C g+,s,b,v for SMU5 (Table 7; Fig. 12). However, the FCC is insufficiently precise to recommend appropriate management for each soil mapping unit in the study area. As a result, modifications to FCC soil ratings should be implemented to properly assess their classes and potential for agriculture.

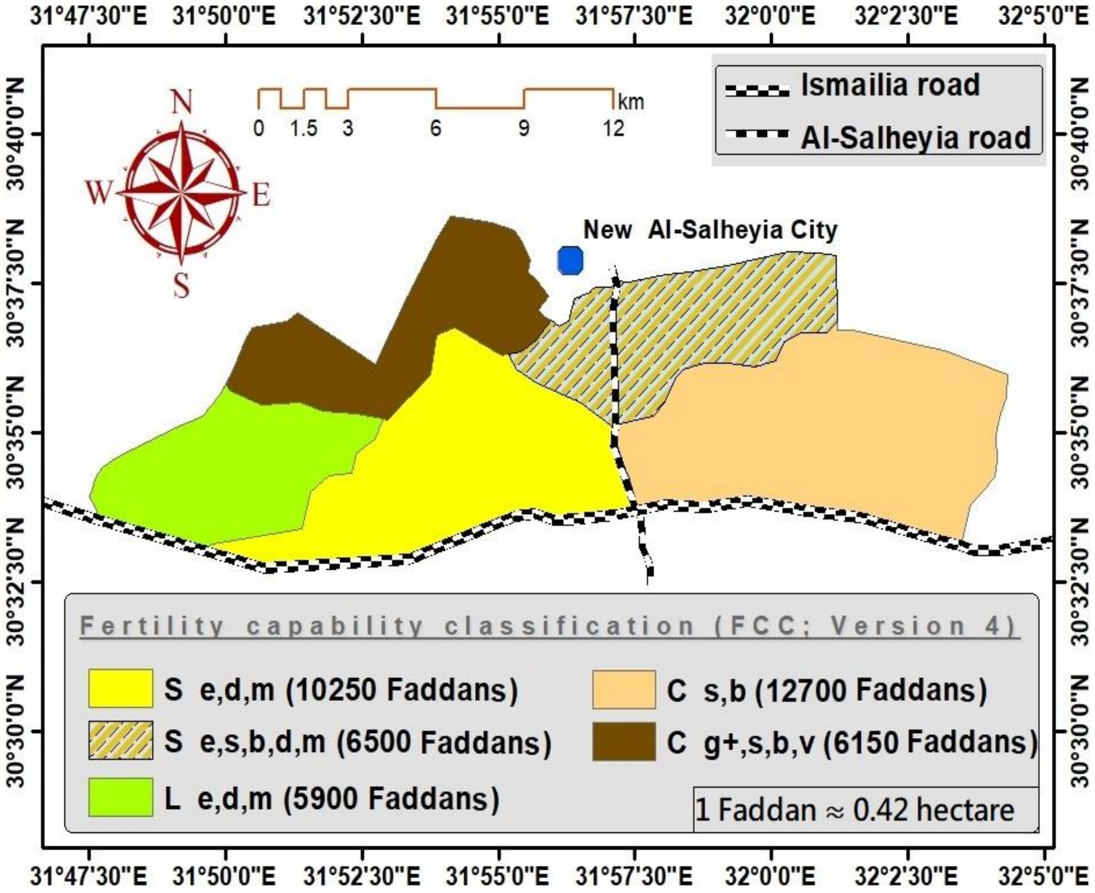


Fig. 12. Classification of studied soils based on fertility capability classification method.

Q_LDLPE classified the lands of the study area into three potentiality classes based on the characteristics of soil parameters, water availability, environment, socioeconomic, and political collections (Table 7; Fig. 13). SMU1 and SMU2 high potential lands cover 16750 Faddans (40.4% of the sampled area). The moderate potential lands (18600 Faddans) occupied 44.8% of the total area (SMU3 & SMU4). SMU5 was occupied by slight (marginal) potential lands (6150 Faddans) (Table 7; Fig. 13). The current study's findings are consistent with those of Elwan and Sivasamy (2013b) in Indian sites, as well as Elwan and Khalifa (2014) in Egypt's Mediterranean region, which emphasized the Q_LDLPE model's global applicability.

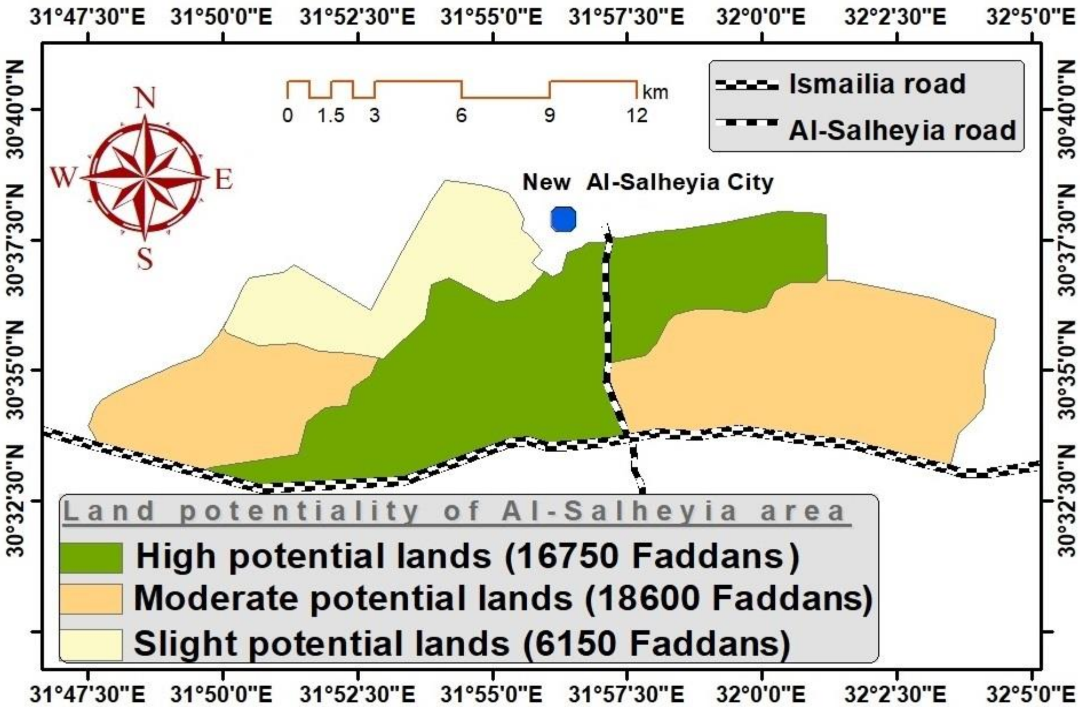


Fig. 13. Land potentiality classes of Al-Salheyia area using Q_LDLPE method (1 Faddan ≈ 0.42 hectare).

Comparison of Tested Land Evaluation Methods

In general, the tested approaches examine many terms linked to site suitability, capability, and potentiality of land/soil for performance evaluation and land use planning. Most USDA LCC, Storie index, FCC, and Q_LDLPE methodologies have been adapted to Indian and Egyptian situations for various forms of land utilization. The efficiency of the investigated approaches in assessing semiarid sites for Desert ecosystem farming in Egypt was compared. However, the use of these qualitative methodologies in a variety of agro-climatic situations remains a difficulty. For SMU5, two approaches yielded comparable findings and were deemed inappropriate for cultivation.

In contrast, LCC, Storie, and FCC assigned more fantastic suitability ratings to SMU4 soils, even though these soils have some significant problems of soil depth (85 cm; moderately deep) and extremely hard layer (Cr) at 55 cm as rooting-zone constraints (Table 7). The appropriateness class for SMU3 differed depending on the tested methodologies. According to the Storie index, these soils were nonagricultural areas, arable land (class-IV) according to the LCC, and moderate potential land according to the Q_LDLPE model. Soils in SMU1 and SMU2 were high potential lands according to Q_LDLPE but poor and very poor according to the Storie index and arable class-IV according to LCC. The capability or potentiality classes determined by the studied methodologies differed for SMU2, very poor by Storie index, class-VI by LCC, and high potential class by Q_LDLPE (Table 7). However, when SMU5 soils were placed in lower suitability classes, the tested procedures produced equivalent outcomes. The Storie index assessed these soils as nonagricultural, the LCC as nonarable, and the Q_LDLPE as having a slight potential.

Data in Table 8 indicate the relationship between the various land appraisal methodologies. The Pearson correlation value between USDA LCC and the Storie index technique is 0.41, showing a low association between them. Furthermore, the correlation between LCC and Q_LDLPE was significant (0.87) and marginally linked with the FCC (0.54). Moreover, there is no relationship between the Storie index and the FCC or Q_LDLPE (Table 8). According to a correlation analysis, the Q_LDLPE exhibited a higher connection with the USDA LCC (0.87) and FCC (0.69) than the Storie index (0.41).

Except for the Q_LDLPE approach, most of the examined soils were located in lower arable classes of suitability or capacity by the tested Storie index and LCC methodologies. The coarse topsoil texture, high salinity, and rooting-zone restrictions lowered the final class by LCC and Storie index. As a result, one or a few constraints may influence Storie's index value, leading to incorrect conclusion or misinterpretation. Furthermore, the Storie index rated the soils of SMU4 as fair (grade 3) to be the best among studied lands for land use, even though these soils have severe limitations related to soil depth, an extremely hard layer of weathered bedrock (Cr) at 55 cm, and high $CaCO_3$ compared to SMU1 and SMU2.

The statistical findings of Table 8 and Table 9 show that the methodologies used to assess land suitability for soil mapping units differ. The kappa coefficient (k) between USDA LCC and observed crop yield in SMU1 is 0.46, indicating moderate agreement. The lowest k values (0-0.43) for the Storie index indicate poor to good agreement, followed by FCC (k=0.49-0.61) and LCC (k=0.44-0.62). The Q_LDLPE model, on the other hand, had the highest k values (k=0.59-0.94), showing a moderate to perfect agreement between potentiality classes provided by this approach and accurate soil attributes associated with crop output.

Table 8. Pearson correlation coefficient (r) of tested systems.

Tested method	USDA LCC	Storie index	FCC	Q_LDLPE
LCC	1.00			
Storie index	0.41^{**}	1.00		
FCC	0.54^{**}	0.39	1.00	
Q_LDLPE	0.87^{**}	0.22	0.69^{**}	1.00
** : At the 0.01 level, it is significant.				

Table 9. Kappa coefficient (k) of tested land evaluation methods and observed crop yield.

Tested method Observed yield	L.C.C.	Storie index	FCC	Q_LDLPE
SMU1 – crop yield	0.46	0.31	0.55	0.94
SMU2 – crop yield	0.51	0.20	0.49	0.67
SMU3 – crop yield	0.62	0.0	0.50	0.62
SMU4 – crop yield	0.55	0.19	0.42	0.76
SMU5 – crop yield	0.44	0.33	0.61	0.59

The lack of correlation between the Storie index and the other tested approaches suggests this method's weakness. Furthermore, the Storie index was developed in the 1920s and 1930s for irrigated soils in California, but it is now widely used in all agroecological situations (O'Geen *et al.,* 2008). Because the index is based on factor multiplication, limiting any factor affects the index value, as demonstrated in surface soil textures with low ratings (see Table 3). Furthermore, because of the arbitrary ranges of parameters, it is very subjective. As a result, the Storie index approach suffers from a substantial disadvantage due to the masking effect of a wide range of values. For example, suppose any parameter, such as the coarse surface texture rating, is close to zero, as indicated in Table (3). In that case, the Storie index result will be close to zero and improper for use, which is wrong. As exemplified in the QLDLPE model, the multi-criteria technique might be used to eliminate the anomalies in the Storie and LCC methods (Ghobadi *et al.,* 2021). The Q_LDLPE considers several land quality indicators (soil properties, environment, political, and socioeconomic criteria) used in the current study and is designed to give unequal weights to all criteria based on the importance of the indicator to soil function (Elwan, 2019). Elwan (2019) argued for a multi-criteria technique for assessing agricultural land in the desert ecosystem. As a result, it is preferable to employ a multi-criteria approach for evaluating desert ecosystems (Ghobadi *et al.,* 2021).

The most significant limiting factor affecting land production in most desert locations studied was coarse soil texture, which signifies a lack of water-holding capacity and soil fertility parameters, requiring most of these resources to be temporarily placed on nonarable land. In the meantime, these soils have previously been cultivated and have cost-effectively produced high crop yields, like in SMU1 and SMU2. One of the main weaknesses of the LCC and Storie land evaluation systems is the coarse soil texture and related property ratings, which is consistent with the findings of Elwan and Sivasamy (2013a). The sandy texture and accompanying features earned very low ratings with severe constraints in the LCC and Storie index guidelines (see Tables 2 & 3). They were evaluated as more than one limiting factor in the same manner. Another critique is that LCC and Storie have disregarded most constraints and concerns related to land as an environment, such as irrigation water supply, cultural issues, labor, infrastructure, market functioning, and socioeconomic and political features. As a result of their ignorance of these factors and concerns, the LCC and Storie index have failed to properly evaluate desert soils. Land and people are the two key elements influencing land appraisal that should be considered, the former because it is limited and the latter because their need for land is rising. Because all of these characteristics were considered in the Q_LDLPE model, it agrees with crop output across various soil mapping units. Sandy soils with good fertigation management have a high potential to overcome other constraints, such as severe salinity and sodicity (as found in SMU2), which can be easily removed from sandy skeletal profiles of SMU1 and SMU2 compared to other fine-textured soils of SMU3 or SMU5 with rooting-zone limitations, which have significant difficulties removing the same level of salinity.

Furthermore, fertility status and soil structure can be improved by applying the appropriate amounts of organic fertilizers, soil conditioners, and biofertilizers. As a result, these resources can be used in agriculture to produce plentiful crops when properly watered (as long as irrigation water is available). As a result, the evaluated land assessment methods of LCC and Storie index gave relatively low ratings for surface soil texture that might be lost due to erosion (Tables 2 and 3). Consequently, they did not represent actual performance and appear unfair for judging the productive potential of desert areas, resulting in the majority of them being classified as unsuitable. Accordingly, planners and the government have excluded desert land resources from planning and development. The Q_LDLPE model, on the other hand, was proved to be the optimum land evaluation approach for assessing desert land ecosystems. Finally, considering all the previously mentioned factors, the Q_LDLPE model is a multidisciplinary approach to land assessment for desert regions. This approach applies to various sizes and provides adequate crop output to calculate the true desert resource potential. It could help decision-makers choose the best usage and preserve agricultural productivity while maintaining soil quality and preventing further soil deterioration and desertification.

CONCLUSION

The Q_LDLPE approach successfully identified the key limits and restrictions in the Al-Salheyia area of Egypt for agricultural desert land evaluation. Based on different soil qualities, five soil mapping units were identified. The morphological characteristics, solum depth, soil texture, $CaCO_3$, water holding capacity, pH, soil salinity, and ECEC of the desert soils studied differed. When four land evaluation methods (the USDA LCC, the Storie index, the FCC, and the Q_LDLPE as a multi-criteria land desert evaluation method) were compared, it was found that the soil-site characteristics of Q_LDLPE performed better in predicting the land potentiality in the Al-Salheyia area than the USDA LCC and the Storie index methods. The kappa coefficient (k) revealed moderate to perfect agreement between Q_LDLPE and predicted crop output in the soil mapping units analyzed. As a result, the current study indicated that caution should be exercised when selecting a method for assessing desert land potential for agricultural production specific to agroecological circumstances. The physical evaluation of soils by LCC, FCC, and Q_LDLPE exhibited distinct significant relationships but few associated with the suitability ratings of the soils-based Storie index. Because they have given very low ratings for the coarse texture of desert soils, either LCC or FCC cannot reflect the actual performance of the desert area of Al-Salheyia. However, Q_LDLPE is preferred as the best method for predicting the soils of desert ecosystems in Egypt and other similar regions. Integration of socioeconomic, political, soil, and environmental factors, as well as their distribution, constraints, and potentials, must be considered in the land evaluation method, as in Q_LDLPE. This approach considerably aids in selecting a specialized approach that can accurately estimate desert ecosystem performance to increase agricultural expansion while offering scientific knowledge to decision-making.

In the current work, the examined land evaluation methods (LCC, Storie index, FCC, and Q_LDLPE) are considered qualitative approaches that do not consider input or output measures of costs or profits based on numerical calculations and empirical equations. Future work should incorporate socioeconomic, political, soil, and water data in quantity measures based on inputs and outputs for each soil and crop type to develop quantitative desert land evaluation methodologies based on various experimental soil, water, and economic data in the desert ecosystem. These methods could be called Quantitative Desert Land Potentiality Evaluation (Q_NDLPE) and Quantitative Desert Land Aptness for Crops (Q_NDLAC). They could be used in many different agricultural enterprises across the globe.

REFERENCES

Ahmed, D.A; Shaltout, K.; Slima, D.F. and El-Masry, S. (2023). Threats affecting the distribution of Lygeum spartum Loefl. Ex L. and its associated species in the Western Mediterranean desert of Egypt: Perspectives of conservation. Journal for Nature Conservation 72: 126351

Artieda, O.; Herrero J. and Drohan, P. (2006). Refinement of the differential water loss method for gypsum determination in soils. Soil Sci. Soc. Am. J., 70(6): 1932–1935.

Awad, S.R., and El Fakharany, Z.M. (2020). Mitigation of waterlogging problem in El-Salhiya area, Egypt, Water Science, 34:1, 1-12, DOI: 10.1080/11104929.2019.1709298.

Egyptian Meteorological Authority (2022). Climatic Atlas of Egypt, Cairo, Egypt.

El-Nashar, W. Y. (2013). The combined effect of water-logging and salinity on crops yield. IOSR Journal of Agriculture and Veterinary Science, 6: 40–49. doi:10.9790/2380-0644049.

Elwan, A.A. (2013). Novel approaches of land evaluation using geospatial technologies for planning sustainable development of desert areas. Ph.D. (Ag) Thesis, Tamil Nadu Agric. Univ., Coimbatore, India.

Elwan, A.A. (2019). Dry Lands, Biodiversity, Management, and Conservation. LC ebook Chapter No. 9: Proper Evaluation of Desert Ecosystem for Sustainable Development. Environmental Research Advances. Nova Science Publishers, Inc., New York.

Elwan, A.A. and Khalifa, M.E.A. (2014). Evaluation of agri-Limitations for sustainable development at the area between El-Dabaa and El-Alamain, Mediterranean Region, Egypt. Alex. J. Agric. Res. 59 (3): 157-168.

Elwan, A.A. and Sivasamy, R. (2013a). Inadequacy of existing land evaluation systems for desert regions development. Zagazig J. Agric. Res. 40 (1), 49-57.

Elwan, A.A. and Sivasamy, R. (2013b). Novel approach of land evaluation for natural resource management of desert ecosystem. Agricultural Graduate Student Conference on Food Safety and Food Security. Madras Agric. J. 100: 156-164.

FAO (1970). Physical and Chemical Methods of Soil and Water Analysis. Soils Bulletin. No. 10, F.A.O., Rome, Italy.

FAO (2006). Guidelines for Soil Description. 4th Edition. Food and Agriculture Organization of the United Nations, Rome, Italy, Pp 97.

Gao, Y. and Li, Z. (2022). Study of coupling coordination development of ecology and economy of Gansu Area of Qilian Mountain National Park in China based on Dfsr model. Fresenius Environ. Bull. 31, 7019–7030.

Gee, G.W. and Bauder, J.W. (1986). Particle-size analysis. In: Klute, A. (Ed.), Methods of Soil Analysis Part 1, Physical and Mineralogical Methods. SSSA Book Series No.5, second ed. SSSA and A.S.A., Madison, Wisconsin, USA, pp. 383–412.

Ghobadi, M.; Nasria, M. and Ahmadiparib, M. (2021). Land suitability assessment (LSA) for aquaculture site selection via an integrated GIS-DANP multi-criteria method; a case study of lorestan province, Iran. Aquaculture 530, 735776.

Hu, W.; Zhang, S.; Fu, Y.; Jia, G.; Yang, R.; Shen, S.; Li, Y. and Li, G. (2023). Objective diagnosis of machine learning method applicability to land comprehensive carrying capacity evaluation: A case study based on integrated RF and DPSIR models. Ecological Indicators 151, 110338.

Iknayan, K.J. and Beissinger, S.R. (2018). Collapse of a desert bird community over the past century driven by climate change. Proc. Natl. Acad. Sci. 115: 8597–8602.

Jackson, M.L. (1973). Soil chemical analysis. Advanced course Ed.2. A manual of methods useful for instruction and research in soil chemistry, physical chemistry of soil, soil fertility and soil genesis. Revised from Original Edition (1955). USA

Kaiser, M.F.; El Rayes, A.; Ghodeif, K. and Geriesh, B. (2013). GIS data integration to manage waterlogging problem on the eastern Nile Delta of Egypt. International Journal of Geosciences, 4: 680–687.

Khan, A.A.; Ruby, T.; Naz, N. and Rafay, M. (2017). Desert Ecosystem Management: A sustainable and wise use. 85-98. In: Sandhu, H. (Ed.), Ecosystem Functions and Management -Theory and Practice. https://doi.org/10.1007/978-3-319-53967-6.

Klingebiel, A.A. and Montgomery, P.H. (1961). Land capability classification. USDA Agricultural Handbook 210. US Government Printing Office, Washington, DC, p. 310. Landon, J.R., 1984. Booker Tropical Soil Manual. Booker Agriculture International, New York, p. 223.

Klute, A. (1986). Water retention: laboratory methods. In: A. Klute (ed) Methods of Soil Analysis. 2nd ed., pt. 1, Madison, WI: pp. 635-662.

Landis, J.R. and Koch, G.G. (1977). "The measurement of observer agreement for categorical data". Biometrics. 33 (1): 159-174.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Mabrouk, B.; Ramadan, F.; Nagaty, M. and Abd El Azeem, Y. (2016). Sedimentological and Hydrogeochemical Studies of the Quaternary Groundwater Aquifer in El Salhyia Area, Sharkia Governorate, Egypt. Middle East J. Appl. Sci., 6(1): 120-138.

Mahmoud, M.A. (2017). Groundwater and agriculture in the Nile Delta. In A. M. Negm (Ed.), Groundwater in the Nile Delta. Cham: Springer, The handbook of environmental chemistry, 73: 141–157.

Meigs, P. (1953). In: World Distribution of Arid and Semiarid Homoclimates, Reviews of Research on Arid Zone Hydrology. UNESCO, Paris, pp. 203–210.

Nelson, D.W.; Sommers, L.E.; Miller, R. and Keeney, D.R. (1990). Total carbon, organic carbon and organic matter. In: Methods of Soil Analysis, 39. Chemical Method, ASA and SSSA, Madison, pp. 1085–1121 .

O'Geen, A.T.; Southard, S.B. and Southard, R.J. (2008). A revised Storie index for use with digital soils information. University of California, Division of Agriculture and Natural Resources. ANR Publications 8335.

Oko-Oboh, E.; Oriaifo, S.; Oviasogie, P.O. and Osayande, P.E. (2017). Capability assessment of some selected soils of shale and basement complex origins in a transitional rain forest ecology in Edo State, Nigeria. J. Agric. For. Fish. 16 (1): 1–9.

Quandt, A.; Herrick, J.; Peacock, G.; Salley, S.; Buni, A.; Mkalawa, C.C.; and Neff, J. (2020). A standardized land capability classification system for land evaluation using mobile phone technology. Journal of Soil and Water Conservation, 1-11. doi:10.2489/jswc.2020.00023.

Rossiter, D.G. (1994). Land Evaluation Lecture Notes. College of Agriculture and Life Sciences, Cornell University, p. 32.

Said, R. (1981). The geological evolution of the River Nile, Springer, Verlag, New York, p: 151.

Sanchez, P.A.; Palm C.A. and Buol, S.W. (2003). Fertility capability soil classification: a tool to help assess soil quality in the tropics, Geoderma, 114,157-185. https://doi.org/10.1016/S0016-7061(03)00040-5.

Shata, A.A. (1965). Geological structure of the Nile Delta. J. of Eng. Cairo, (in Arabic), 1-3.

Shata, A.A. and El Fayoumy, I.F. (1970). Remarks on the regional geological structure of the Nile Delta. Symposium Hydrology of Delta, UNESCO, I, 189-197.

Soil Survey Staff (2014). Kellogg Soil Survey Laboratory methods manual. Soil Survey Investigations Report No. 42, version 5.0. R. Burt and Soil Survey Staff (eds.). Washington DC: US Department of Agriculture-Natural Resources Conservation Service.

Soil Survey Staff (2022). Keys to Soil Taxonomy, 13th edition. USDA Natural Resources Conservation Service, Washington, DC.

Soltanpour, P.N. and Schwab, A.P. (1977). A new soil test for simultaneous extraction of macro – and micro–nutrients in alkaline soils. Commun. Soil Sci. Plant Anal. 8: 195-207.

Storie, R. (1978). Storie Index Soil Rating. University of California Division of Agricultural Sciences Special Publication, Oakland 3203.

Tercan, E. (2021). Land suitability assessment for wind farms through best-worst method and GIS in Balıkesir province of Turkey. Sustainable Energy Technologies and Assessments 47: 101491.

Thomas, C.G. (2010). Land Husbandry and Watershed Management. Kalyani Publishers, New Delhi, p. 716. Udoh, B.T., Ogunkunle, A.O., Akpan, U.S., 2013. Fertility capability classification of acid sands (soils) as influenced by parent materials in Akwa Ibom State, Nigeria. Niger. J. Soil Sci. 23 (1): 56–66.

Vasu, D.R.; Srivastava, N.G.; Patil, P.; Tiwary, P. and Chandran, S.K.S. (2018). A comparative assessment of land suitability evaluation methods for agricultural land use planning at village level. Land Use Policy 79: 146–163.

Wang, X.; Geng, X.; Liu, B.; Cai, D.; Li, D.; Xiao, F.; Zhu, B.; Hua, T.; Lu, R. and Liu., F. (2022). Desert ecosystems in China: Past, present, and future. Earth-Science Reviews 234, 104206.

Wen, Y.; Zhang, G. and Zhang, W. (2023). Distribution patterns and functional characteristics of soil bacterial communities in desert ecosystems of northern China, Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2023.167081

Whitford, W.G. (2002). In: Ecology of Desert Systems. Academic Press, San Diego, California, p. 343.

Wubalem, A. (2023). Modeling of land suitability for surface irrigation using analytical hierarchy process method in Belessa Districts, northwestern Ethiopia. Heliyon 9, e13937.

مقارنة بين بعض طرق تقييم الأراضى على النظام البيئى الصحراوى فى مصر دراسة حالة: منطقة الصالحية - شرق الدلتا.

عادل عبدالحميد علوان خليل و محمد عزت عبدالهادي خليفة
قسم البيدولوچي، شعبة مصادر المياه والأراضي الصحراوية، مركز بحوث الصحراء، القاهرة، رقم بريدي ١١٧٥٣

الملخص العربى

تختلف طرق تقييم الأراضي في النهج ولم تظهر دائمًا نتائج إيجابية عند تطبيقها على الأراضي خارج المناطق التي تم تصميمها فيها. تم إجراء هذا البحث على مساحة ٤١٥٠٠ فدان (≈١٧٤٣٠ هكتار) بأراضي الصالحية بشرق الدلتا، وهي أراضي صحراوية المنشأ وتحت عمليات الإستزراع. إستهدفت هذه الدراسة مقارنة فعلية على أرض الواقع بين مجموعة من أنظمة تقييم الأراضي من أجل الوصول إلى نموذج فعال لتقييم الاراضي الصحراوية بصورة صحيحة يعكس صفاتها الحقيقية وإنتاجية محاصيلها (في حالة كونها مزروعة). ولتحقيق ذلك؛ تم استخدام طرق مختلفة لتقييم الأراضي وهي: النظام الأمريكي لتقييم قدرة الأرض الانتاجية (USDA LCC)، ومؤشر ستوري Storie index، ونظام تصنيف قدرة التربة الخصوبية (FCC)، ونظام تقييم قدرة الأراضي الصحراوية الكامنة (Q_LDLPE) حيث دراسة مدى توافقهم وأدائهم المناسب لتقييم القدرة الإنتاجية للأراضي تحت الدراسة. تمت دراسة العديد من الصفات المختلفة للتربة والمتعلقة بالوصف المورفولوچي لعدد من قطاعات التربة الممثلة لمنطقة الدراسة، وكذلك تحليل الصفات الفيزيائية والكيميائية وكذلك الخصوبية لعينات التربة التي جُمعت من آفاق قطاعات التربة المدروسة. إستناداً إلى عمق قطاع التربة والقوام وملوحة التربة ومحتواها من كربونات الكالسيوم، تم تحديد خمس وحدات تربة خرائطية (SMUs) بمنطقة الدراسة. أوضحت النتائج إلى أن التربة ذات قطاع عميق إلى متوسط، خشنة إلى ناعمة القوام، غير ملحية إلى شديدة الملوحة، متوسطة إلى شديدة التأثر بالجير. تم تصنيف الأراضي تحت الدراسة طبقاً لنظام LCC إلى ثلاثة فئات: فئة زراعية ثالثة Class-III (٥٩٠٠ فدان؛ ١٤,٢٪)، فئة زراعية رابعة Class-IV (٢٩٤٥٠ فدان؛ ٧١٪)، وفئة غير زراعية خامسة Class-V (٦١٥٠ فدان؛ ١٤,٨٪). بينما صُنفت التربة تحت الدراسة طبقاً لمؤشر ستوري إلى أربع فئات: معتدلة Fair (٥٩٠٠ فدان)، ضعيفة Poor (١٠٢٥٠ فدان)، ضعيفة جداً Very poor (٦٥٠٠ فدان)، وتربة غير زراعية Nonagricultural (١٨٨٥٠ فدان). وفقًا لتصنيف نظام LCC ومؤشر ستوري Storie index ، كانت التربة ذات مُحددات شديدة تتعلق بخشونة قوام التربة خاصة بالطبقة السطحية لوحدتي التربة الخرائطية الأولى والثانية (SMU1&2)، وكذلك درجة الملوحة، ومدى وجود ظروف الغدق Waterlogging بطبقات قطاع التربة خاصة أراضي الوحدة الخرائطية الخامسة SMU5. بالاضافة إلى أنه تم تقسيم نفس التربة المدروسة إلى خمس مجموعات طبقاً لنظام FCC والتي تختلف فيما بينهم في قوام الطبقة السطحية وعدد من المُحدات الأخرى، حيث تمتلك الاراضي ذات القوام الناعم بعض المُحدات شديدة التأثير والتي من أبرزها إرتفاع منسوب مستوى الماء الأرضي والذي تسبب في ظاهرة غدق المياه، وزيادة تركيز الاملاح، بالاضافة الى زيادة نسبة كربونات الكالسيوم التي تسبب في ظهور الطبقات المتصلبة خلال قطاع التربة مما يقلل من الصرف الطبيعي للماء الزائد والاملاح، كما لوحظ إنخفاض السعة التبادلية الكاتيونية المؤثرة ECEC والمادة العضوية OM في الأراضي خشنة القوام. وفي النهاية، تم تقسيم التربة بناءً على نظام Q_LDLPE إلى ثلاث فئات: خفيفة الانتاجية Slight (٦١٥٠ فدانًا)، معتدلة أو متوسطة الانتاجية Moderate (١٨٦٠٠ فدانًا)، وعالية High (١٦٧٥٠ فدانًا).

ومن خلال التحليل الاحصائي بين أنظمة التقييم تحت الدراسة فيما بينهم، فنجد أن تحليل الارتباط Correlation analysis كشف عن وجود إرتباط محدود أو قوي ما بين LCC و FCC و Q_LDLPE، لكن معامل الارتباط لمؤشر ستوري Storie كان الأقل. تم تحديد معامل الكابا(k) Kappa coefficient بين نتائج أنظمة تقييم الأراضي وإنتاج المحاصيل الفعلي بالمزرعة والذي تم ملاحظته بنطاق الأراضي تحت الدراسة. فقد أوضحت الدراسة الإحصائية أن أعلى قيم

لمعامل كابا Kappa coefficient كانت ما بين نتائج نظام Q_LDLPE وإنتاج المحاصيل الفعلية والتي تم ملاحظته بمنطقة الدراسة، فقد تراوح بين اتفاق معتدل Moderate agreement واتفاق مثالي Perfect agreement (٠,٥٩-٠,٩٤) ، مما يشير إلى أن هذا النظام (Q_LDLPE) هو أداة قوية لتوقع أداء حقيقية لقدرة التربة الإنتاجية وخاصة بالبيئة الصحراوية، لانه نظام يشمل كافة معايير التربة، والمياه، والبيئة. وعلاوة على ذلك، فقد أظهر كلاً من مؤشر ستوري Storie وكذلك نظام USDA LCC عجزًا عن تغطية جميع صفات التربة والمعايير الاجتماعية والسياسية والبيئة، حيث لوحظ ان أغلب هذه الانظمة أعطت للقوام الرملي وخواص التربة المرتبطة أقل معدلات التقييم المستخدمة فى تقدير وتقييم قدرة وأداء هذه الاراضى، ايضا أعطت لهذه المحددات اكثر من عامل محدد للانتاجية فى نفس نظام التقييم المتبع، مع العلم ان احد هذه العوامل يعكس الاخرى، بالرغم من ذلك، نجد على أرض الواقع ان أغلب أراضى هذه المنطقة مزروعة بالفعل بصورة إقتصادية وذلك لأن الاراضى الصحراوية تحت برامج الرى والتسميد الملاءمة تُعطى أعلى انتاجية محصولية. في حين أظهرت هذه الدراسة أن Q_LDLPE هو أسلوب متعدد المعايير وبواسطته تم توقع القدرة الإنتاجية للتربة الصحراوية بكفاءة عالية ومتوافقة مع الواقع الحالي لصفات التربة وإنتاجية المحاصيل بها، فهو أداة وصفية Qualitative ومتخصصة لتحسين النظام البيئي لموارد الصحراء و إدارتها بصورة مُستدامة. وعلاوة على ذلك، فنجد ان جميع أنظمة التقييم المختبرة في هذه الدراسة هي أساليب نوعية ووصفية Qualitative لا تأخذ في الاعتبار معايير اقتصادية بشكل صريح كتحليل المدخلات والمخرجات بأراضي المزرعة بصورة إقتصادية وكمية Quantitative inputs and outputs as profits. في المستقبل القريب، يجب اختبار وتصميم منهجيات وأنظمة تقييم الأراضي الصحراوية الكمية والاقتصادية (Quantitative desert land potentiality evaluation, Q_NDLPE) القائمة على المقاييس الكمية والاقتصادية لكافة المدخلات والإيرادات المتوقعة من أجل تقييم اقتصادي فعال للموارد الأرضية في النظام البيئي الصحراوي.