Assiut J. Agric. Sci., 52 (2) 2021 (100-119) *ISSN: 1110-0486*
Website:www.aun.edu.eg/faculty_agriculture/journals_issues_form.php *E-mail: ajas@aun.edu.eg*

Land Capability of the Middle Part of Wadi Qena, Eastern Desert, Egypt and Its Suitability for Growing Crops

Attia, M.K.K.; M.A. Gameh; M.A. El-Desoky and S.H. Abd El-Aziz

Soil and Water Dept., Faculty of Agriculture, Assiut University, Egypt

Accepted for publication on: 20/8/2021

Abstract

Wadi Qena is one of the largest dry valleys in the eastern desert of Egypt for the agricultural expansion. This study attempted to investigate the best agricultural land use of the middle part of this Wadi through its capability and suitability assessment based on its soil characteristics. So, forty-nine soil profiles were selected and digged to represent the soils of this area in February, 2017. One hundred and thirty six soil samples were collected from these profiles, to perform the physical and chemical analyses.

Sand, loamy sand and sandy loam textures were in this area. High variabilities were recorded in the soil salinity (ECe), soil alkalinity (ESP), total calcium carbonate content, soil pH, available N, P and K, soil depth which they varied from 0.83 to 187.6 dSm^{-1}, from 7.41 to 17.8%, from 7.31 to 51.19%, from 7.70 to 8.81, from 2.3 to 88.8 mg kg^{-1}, from 1.82 to 11.06 mg kg^{-1} and from 40 to 920 mg kg^{-1} and from 50 to >150 cm, respectively. Also, the hydraulic conductivity (HC), the field capacity (FC), the wilting point (WP) and available water capacity (A.W.C) values vary from 2.92 to 38.00 cm/h with an average of 23.32 cm/h, 10.50 to 26.54 v/v % with an average value of 17.03 v/v %, 4.36 to 12.61 v/v % with an average of 7.63 v/v %, and from 4.96 to 18.13 v/v % with an average of 9.40 v/v %, respectively.

The studied soils were fair, poor and non-agricultural capable for agricultural uses. The dominant limiting factors for agricultural use were the coarse soil texture, high salinity and alkalinity, low organic matter content and CEC, as well as the high $CaCO_3$ content.

Results of Agricultural Land Suitability Evaluation (ASLE) software analysis showed that the soils of the study area ranged from S2 (suitable) to NS1 (currently not suitable) for growing wheat, barley, sugar beet, sunflower, pepper, watermelon, date palm, olive, fig and grape. They also varied from NS1 (currently not suitable) to NS2 (permanently not suitable) for growing rice, cotton, sugarcane, onion and cabbage.

The prevailing limiting factors affecting the suitability of these soils for growing different crops were those of the capability as well as the low nutrient availability. Also, an urgent need is required for specific land improvements of the study area such as controlled fertilizing system, special methods for irrigation and removing gravels. It is recommended to use the organic agriculture system in such region for achieving high economic feasibility.

This study presents a valuable source for governmental agencies concerned about land reclamation projects along with sustainable agricultural development in such desert areas.

Keywords: *Land suitability, Land evaluation, ASLE, Arc GIS, sustainable agriculture, Land capability, Wadi Qena.*

Introduction

Wadi Qena is a part of the eastern desert. It is one of the largest basins, where it runs opposite to the Nile river (obsequent Wadi) from north to south for two degrees of latitude. It is bound by longitudes 32° 30' to 33° 30'E and latitudes 26° 00' to 28° 00'N and covers a total area of 18000 km^2. It is located east of Qena city and constitutes the western part of the eastern desert plateau, Wadi Qena is considered as one of the most promising area for agricultural expansion in Egypt. The study area is characterized by a good labor resource, and is accessible through numerous paved roads.

The climatic conditions of the Eastern desert of Egypt are characterized by an extreme aridity, a high evaporation rate, low relative humidity and a short rainy cool winter. At Qena city, the mean maximum annual temperature was 22.7°C. Every year, more than eight months have a mean monthly maximum air temperature exceeding 30°C, particularly from March to October. The highest temperature (40.9°C) was recorded during June, July and August, whereas the lowest value (21.0°C) was recorded during January. The annual mean minimum temperature ranges from 6.7 to 24.1°C which is recorded in January and February. However, the monthly average temperature fluctuates between 14.7 and 32.4°C. Generally, the rainfall in the study area is rare or trace all over the year. The total annual rainfall ranges from 0.7 to 3.47 mm in Qena according to the Egyptian Meteorological Authority (EGMA, 2004). The degree of aridity in this study varies from 0.05 to 0.44. The highest value of relative humidity (66%) was recorded at the northern part of Wadi Qena. Generally, the values of relative humidity in the study area in winter are high which they reach the maximum range in November, December and January. The average maximum monthly mean value of the evaporation is 23.5 mm during June, while the minimum value is 3.1 mm during December (Awad, 2008 and EGMA, 2016).

Wind is considered as one of the geomorphologic factors that obviously participate in forming the geomorphologic features in the area. Mostly, the north winds usually prevail except in winter when the west wind dominates. It is noticed also that the wind speed increases in the spring and summer. Prevailing winds below from northwest to the southeast with an average maximum speed of 10 knots (EGMA, 2004).

The geology, surface water and ground water of the middle part of the eastern desert attracted the attention of many workers. The surface of the Eastern desert is occupied by different types of rocks belonging to various geological ages from the pre-Cambrian to Cenozoic areas (Assiut University, 2001; Abdel Moneim, 2005; Abdel Moniem *et al.*, 2015). Accordingly, the main rock formations occupying the surface of the Eastern desert could be summarized in Fig. 1 (EGS, 1979).

The geomorphologic features of Wadi Qena are a direct reflection of both the tectonics and sedimentary processes. The morphotectonic pattern of the basin is directly affected by the Red Sea fault trend structures. It appears that sedimentary processes, colluviation, erosion and deposition by water and wind actions morphed the landscape of the study area. Accordingly, the study area can be divided into five local landforms (geomorphic units), namely, table and relices, fluviate hummocks, terraces, mouth hills and Wadi plains (El-Shamy, 1988).

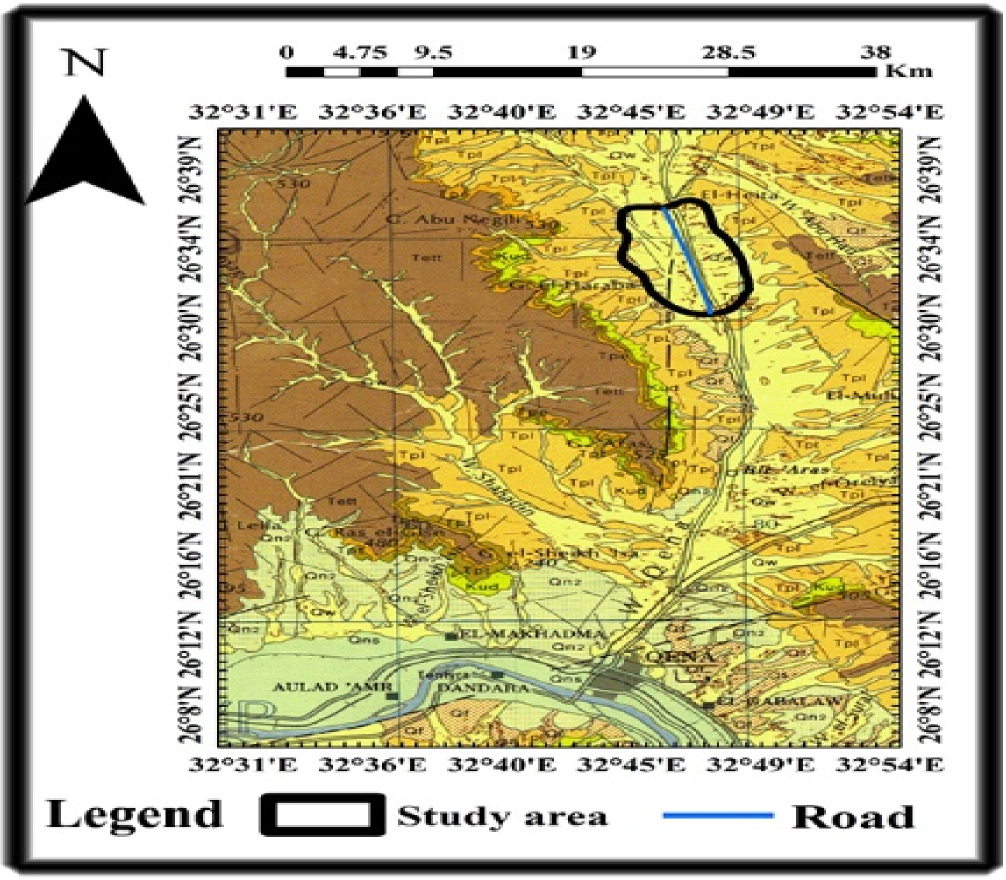

Fig. (1): A geological map showing the study area location (EGS, 1979).

Land evaluation is concerned with the assessment of land performance when used for specified purposes (FAO, 1976). The potential of land for agricultural use is determined by an evaluation of the factors affecting the agricultural land productivity and suitability, such as climate conditions, soil characteristics, and water irrigation quality. This evaluation is an essential step for the agricultural development of an area. Additionally, the identification and accurate description of current and potential production areas are essential for agricultural development, giving the important effect of these factors on the transfer of agro-technological innovations (Corbett, 1996). From this perspective and based on a large amount of data and a large number of criteria used in determining agricultural land use suitability, the assessment of land suitability is recognized as a multi-criteria evaluation (Lee, 2003). Although several land evaluation models have been developed to provide a quantified procedure to match land with various actual and proposed uses, there is no single or unified land evaluation modeling approach (Rossiter, 1996 and 2003).

With commencing the reclamation of a new area, adequate studies should be conducted in that area. The evaluation of lands in terms of their production capacity and their suitability to grow different crops is very important for decision-makers to achieve better utilization of these lands. Growing the suitable crops will achieve the highest land productivity. There are many methods used to evaluate and classify land capability, such as FAO (1976), Storie index (1954), Sys and Verheye (1975) and Ismail and Morsi (2001). These methods are applied to evaluate the lands and classifying them into several capability categories according to their quality. These methods depend on the use of different soil data such as physical, chemical, and fertility properties. Soil suitability for growing different crops can be assessed using different methods that depend on the use of soil parameters and climate data as well as crops-requirements data. The parametric method is commonly used for its comprehensiveness and ease of application (Sys *et al*., 1993). The Agricultural Land Suitability Evaluation (ASLE) model (Ismail and Morsi, 2001) has proven to be very efficient, easy and fast to use. Integration between GIS, methods of assessing land capability and suitability is important for better utilization of land (Panigrahy *et al*., 2006).

The production of land capability and suitability maps can benefit farmers and decision makers in using the land to make the optimal use to achieve high land productivity. Therefore, this study aims to (i) investigate the soil properties of the middle part of Wadi Qena, Eastern Desert, Egypt, (ii) evaluate its capability using the modified Stories Index (O'Geen *et al*., 2008) and the applied system land evaluation (ASLE) (Ismail and Morsi, 2001), and (iii) assess its suitability for growing different crops.

Materials and Methods

Study Area Description:

The investigated area is located in the middle part of Wadi Qena, Eastern Desert, Egypt (Fig. 2). It is limited between longitudes 32° 44' to 32° 49'E and latitudes 26° 30' to 26° 36'N. It lies the north of the proposed Golden Triangle, about 135 km from Sohag city and about 83 km from Safaga city. It extends for 60 km starting from the interaction of Sohag-Qena-Safaga highways at the middle part of the Wadi Qena. The Wadi expands from east to west when the wadi mouth is about 5 km and increases in width to the west reaching more than 15-30 km at the eastern part of the Nile Valley.

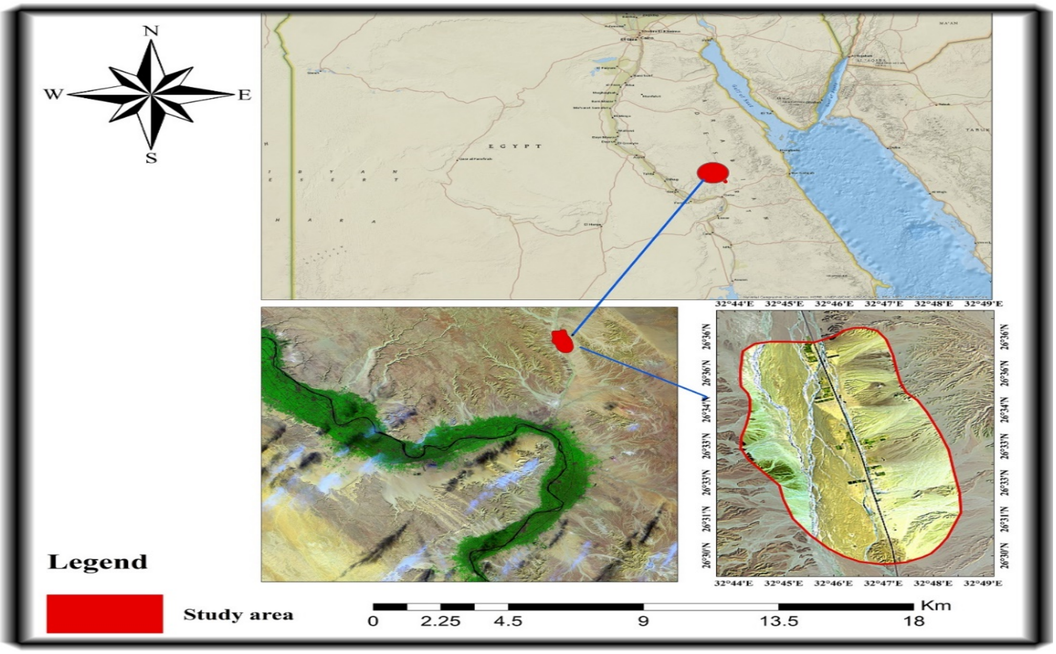

Fig. (2): The location map of the study area.

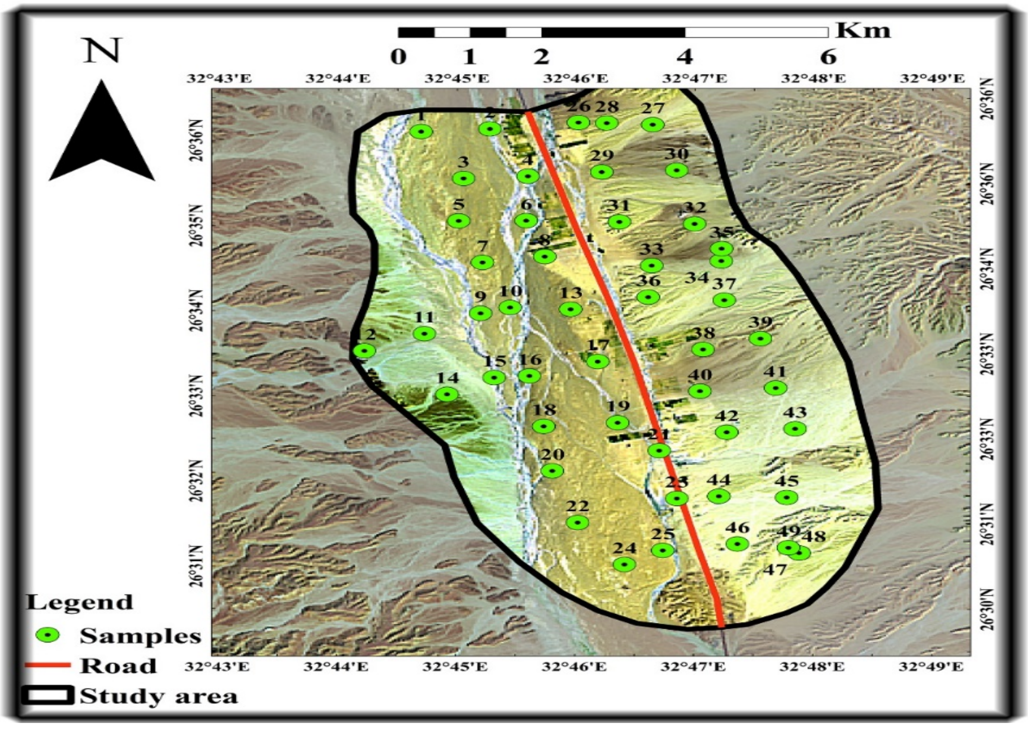

Fig. (3): The location map of the investigated soil profiles in the study area.

Field work and Laboratory Analysis:

Forty-nine soil profiles were chosen to represent the study area (Fig. 3). Twenty-five profiles (Profiles 1 to 25) represented the first location which lies on the right-side of Qena-Safaga road and twenty-four profiles (profiles 26 to 49) represented the second location which is on the left side of Qena-Safag road. The profiles were selected according to the morphological variation (Fig. 3). Locations of these soil profiles were recorded in the field using the global positioning system (Garmin G.P.S). Each profile was dug down to a depth of 2 m unless it was hindered by a bed rock or water table. All soil profiles were morphologically described according to the standard procedure and terminology that were reported by FAO (2006) and Schoenberger *et al*. (2012). Soil samples (136 samples) were collected from the different layers of all investigated soil profiles according to vertical morphological variations.

The collected soil samples were air-dried, crushed, sieved to pass through 2 mm sieve and stored in plastic containers for different analysis. The main physical and chemical properties of the studied soil samples were determined according to some standard physical and chemical analysis. Soil color was determined under both dry and moist conditions using Munsell color charts (Soil Survey Staff, 1975). The particle size distribution was done by the international pipette method (Jackson, 1969). Soil bulk density was determined using undisturbed soil cores according to Blake and Hartge (1986). Hydraulic conductivity (HC) was measured using a constant head system for conductivity measurement according to Klute and Dirksen (1986). Field capacity (FC) and Permanent wilting point were determined using the Pressure membrane apparatus at 1/3 and to 15 atm, respectively (Klute, 1986). Soil available water capacity (A.W.C) was estimated according to Siderius (1992). Saturation percentage (SP) was measured as described by Hesse (1998). Soil reaction (pH) and electrical conductivity (ECe) were determined in 1:1 soil-water suspension and soil paste extract, respectively. Calcium carbonate content was estimated volumetrically using a Colins's calcimetr (Jackson, 1973). Organic matter content was determined by Walkley and Black method (Jackson, 1973). Cation Exchange Capacity (CEC) was determined using 1M sodium acetate (pH= 8.5) as a saturation solution and 1 M ammonium acetate (pH = 7) as a replacement solution (Jackson, 1973).

Exchangeable sodium percentage (ESP) was calculated as the percentage of exchangeable Na of the CEC. Available N-NH_4 was extracted with 1% K_2SO_4 at ratio of 1:5 and using Devarda's alloy and determined by the micro kjeldah's method (Jackson, 1973). Available phosphorus was extracted with 0.5 M $NaHCO_3$ solution at pH= 8.5 and determined following the procedures outlined by Olsen *et al* (1954) and Jakcson (1973). Available potassium was extracted using 1 M ammonium acetate (pH= 7.0) method and measured by a flame photometer.

The data of each profile were transformed into a weighted mean. The weighted mean value for each soil property (V) was calculated by multiplying the summation of (Vi) for each layer by its thickness (ti) and divided by the profile depth (T) according to Moursy *et al* (2020a) as follows:

$$V = \sum_{t=1}^{n} \frac{(V_i \, x \, t_i)}{T}$$

Soil Classification:

Based on the recorded meteorological data, pedo-morphological descriptions and analytical soil properties, the investigated soil profiles were classified down to the subgroup level according to Soil Taxonomy (Soil Survey Staff, 2014).

Land Evaluation:

The studied soils were evaluated for land capability and land suitability using several systems as follow:

1. Land capability:

a. Modified Storie index rating:

In this system, the rating and coding for some soil properties are calculated using visual basic application under Microsoft Excel, according to Aldbaa (2012). The storie index was calculated according to O'Geen *et al*. (2008) as follows:

Storie Index= [(A/100) x (B/100) x (C/100) x (X/100)

Where:

A= Soil profile depth (cm).

B= Soil texture,

C= Slope and

X= Other soil factors that include, topographic drainage, fertility, nutrient level, erosion, micro relief and alkalinity. Table 1 shows the land capability classes, soil grade and productivity rating, using the modified storie index (O'Geen *et al*., 2008).

Table 1. Land capability classes soil grades and productivity rating using the modified storie Index (O'Geen *et al*., 2008).

Soil factor	Soil properties	Capability classes	Grade	Productivity rating (%)
A	Physical properties	Excellent	Grade 1	80 – 100
B	Soil texture	Good	Grad 2	60 – 79
C	Slope	Fair	Grade 3	40 – 59
		Poor	Grade 4	20 – 39
X	Other soil factors	Non agricultural	Grade 5	<20

b. Applied system of land evaluation (ASLE):

This software was proposed by Ismail and Morsi (2001) for arid and semi-arid regions. It was applied to evaluate the land capability of the investigated area. This software works interactively to compare the characteristics of land units to be evaluated with the generalization levels established for each use capability class (C1, C2, C3, C4, C5 and C6). The prediction of capability classes is the result of the qualitative process or the overall interpretation of some soil characteristics such as, soil profile depth, relief, climate, ground water depth, soil chemical and physical properties and soil fertility. Table 2 displays land capability classes, soil grades and rating according to Ismail and Morsi (2001).

Table 2. Land capability classes, soil grades and rating using ASLE software (Ismail and Morsi, 2001).

Class	Grade	Rating (%)
C1	Excellent	80 – 100
C2	Good	60 – < 79
C3	Fair	40 – < 59
C4	Poor	20 – < 39
C5	Very poor	10 - < 19
C6	Non agricultural	<10

2- Land suitability:

The applied system of land evaluation (ASLE) software for arid and semi-arid regions (Ismail and Morsi, 2001) was used to assess land suitability for growing some field crops, forage crops, vegetables and fruit crops on the soils of the study area. The software calculations were done based on matching the crop requirements with land qualities according to FAO (1976). Table (3) shows the land suitability classes, grades and rating using the ASLE software according to Ismail and Morsi (2001).

Table 3. Land suitability classes using the ASLE Software (Ismail and Morsi, 2001)

Class	Grade	Index (%)
S1	Highly suitable	80 – 100
S2	Suitable	60 – < 79
S3	Moderately suitable	40 – < 59
S4	Marginaly suitable	20 – < 39
NS1	Currently not suitable	10 - < 19
NS2	Permanently not suitable	<10

Results and Discussion

1- Soil Characterization:

The investigated soils are weakly developed and reflect the prevailing climatic conditions. The only observed diagnostic horizons are Calcic and salic horizons as well as the ochric epipedon. Accordingly, the soils could be classified as Aridisols and Entisols. Additionally, the torric moisture regime and the dominant sand texture lead to classify these soils as subgroups Typic Haplocalcids, Typic Haplosalids and Typic Torripsamments.

The descriptive statistics of the selected main physical and chemical properties of soil samples collected from the study area are listed in Table (4). Descriptive statistics, revealed considerable variability in the soil properties of the investigated soil profiles (Table, 4). The data demonstrate that the soil characteristics vary in the range, minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV).

The range values of the studied soil characteristics vary from 0.08 to 88.0 among the soil profiles, which indicate that some soil properties have very high difference between their minimum and maximum values such as depth, ECe, available K, available N, $CaCO_3$, CEC, and HC. On the contrary, the range values of bulk density, organic matter and pH indicated that their minimum and maximum values are close to each other.

The average values of investigated characteristics varied from 0.34 to 213.24 among the soil profiles. The high mean values are found for available K and soil depth, while the low values are recorded in the other studied properties. The standard deviation (SD) values ranged from 0.27 to 156.16 among the studied characteristics. A low the standard deviation indicates that the data points tend to be close to the mean of the set such as pH and OM, while a high standard deviation indicates that the data points are spread out over a wide range of values such as soil depth and sand. Ranking the coefficient of variation (CV) of soil properties into different classes including least (<15%), moderately (15- 35%), and highly (> 35%) variable according to Wilding (1985).

The coefficient of variation (CV) differs from one variable to another and it varies from 3.25 to 95.51% among all soil characteristics. It indicates that the variability is low for pH (CV= 3.25%), moderate for sand, bulk density, ECe, FC, WP, AWC, ESP, $CaCO_3$, CEC and high to very high for the rest properties with, values of coefficient of variation (CV) that vary from 38.78 to 131.09%. The high to very high variability in soil properties may be to the human and/or natural conductions such as agricultural management practices, nature of soils and climate conditions. The highest variations is recorded in soil HC, organic matter and sand fraction (131.09, 95.51 and 91.18%, respectively). Which is easy to respond either negatively or positively to the agricultural management practices and climate conditions, while the lowest one is observed in the soil pH (CV= 3.25%) which is difficult to be affected by such conditions due to the buffering capacity of soils for pH change.

Soil depth ranged from shallow to deep homogeneous soil (50 to 200 cm) with an average value of 139.80 cm. The particle size distribution analysis showed that the soil samples were dominated by sand (37.14 to 99.57%) with an average of 81.61%, silt ranged from 0.04 to 50.18% (average 12.25%) and clay ranged from 0.2 to 19.05% (average 6.15%). Thus, they had coarse textures with low variation among the soil samples (CV= 17.71%) for sand fraction. The bulk density ranged from 1.34 to 1.75 Mg/m^3 (average 1.54 Mg/m^3). The hydraulic conductivity (HC) varies from 2.92 to 38.00 cm/h with an average 23.32 cm/h (cv= 58.96%). The obtained data showed that volumetric water content at welting point (WP) ranged from 4.36 to 12.61% (average 7.63%) the water content of field capacity (FC) ranged from 10.5 to 26.54% (average 17%). available water capacity (AWC) ranged from 4.96 to 18.13% (average 9.40%) with a moderate variations (CV= 25.68, 28.36 and 33.21%, respectively. that obtained results indicated that the soils are having low water supply power which is attributed to the course texture and low organic carbon.

The electrical conductivity of the saturated soil paste (ECe) of the soil samples range from 0.83 to 187.6

dSm^{-1} and having a high coefficient of variation (CV= 131.09%). The soil pH measured varied from 7.7 to 8.81 representing a neutral to highly alkaline soil conditions and showing a low coefficient of variation (CV= 3.25%). The exchangeable sodium percentage (ESP) of the investigated soil samples, differed from 7.41 to 17.8% with a moderate variations (CV= 25.64%). The total calcium carbonate content ranged from 7.31 to 51.19% with a moderate CV (31.12%). Although the soil organic matter content (SOM) and available phosphorus had a very narrow range (0.02-0.98% and 1.82 to 11.06 mg kg^{-1}, respectively), they have high and low variations among soil samples (CV= 91.18 and 38.78%, respectively). The cation exchange capacity (CEC) varied from 1.91 to 28.26 $cmol^{(+)}$ kg^{-1} with a moderate variation among soil samples (CV= 50.3%).

Regarding the nutrient status of the soils, the available N, and P were low showing 2.3 to 88.8 mg/kg with an average value of 25.36 mg/kg for N, from 1.82 to 11.05 mg/kg with an average value of 4.90 mg/kg for P and, the available K ranged from 40 to 920 mg/kg with an average value of 213.24 mg/kg. The low soil fertility status of the studied soils is mainly attributed to the low soil organic matter content and low nutrients as well as the low water holding capacity. Based on the obtained data, the deficiency of nutrients are expected under these prevailing soil and climate conditions and corrective measurements are urgently required to enhance the soil fertility status. The obtained result were consistent with those reported by Attia *et al.* (2016) and Moursy *et al.* (2020a and b).

Regarding the morphological parameters of soil profiles, the soil depth of all studied profiles was more than 120 cm which is categorized as moderate deep to deep. The color of the soil samples ranged from pink to light yellowish brown under dry conditions, and from very pale brown to brown under wet conditions. Color chroma varied from 4 to 6 in both dry and moist conditions according to Munsell color charts (Soil Survey Staff, 1975). The elevation of the study area differed from 118 to 208 meters above sea level. The slope of the area did not exceed 1% in most profiles and the soil profiles were well drained according to Eliwa *et al.* (2006) and Moursy *et al.* (2020a). The gravel percentage ranged between none and 66.71%. About 38% of the total area was free from gravels, 45% had gravels less than 20%, 25% showed gravels of 20-50% and 4.44% gravels of the total area displayed more than 50% gravels. These soils had a coarse texture including, sand, loamy sand, sandy loam representing 43.38, 20.59 and 30.88% of the study area, respectively, whereas the silt loam and loam textures showed 0.74 and 4.41% of the study area, respectively.

Table 4. Descriptive statistics of selected soil properties of the middle part of Wadi Qena, Eastern desert, Egypt.

Parameter	Minimum	Maximum	Range	Average	SD	CV %
Depth (cm)	50.00	500.00	450.00	139.80	62.93	45.01
Clay (%)	0.20	19.05	18.85	6.15	4.23	68.78
Silt (%)	0.04	50.18	50.14	12.24	11.69	95.51
Sand (%)	37.14	99.57	62.43	81.61	14.45	17.71
Bulk density (Mg/m^3)	1.34	1.75	0.08	1.54	0.42	27.27
ECe (dSm^{-1})	0.83	187.60	186.77	30.27	39.68	131.09
H.C (Cm/h)	2.92	38.00	35.08	23.32	13.75	58.96
F.C (v/v %)	10.50	26.54	16.04	17.03	4.83	28.36
W.P (v/v %)	4.36	12.61	8.25	7.63	1.96	25.68
A.W.C (v/v %)	4.96	18.13	13.17	9.40	3.12	33.21
pH (1:1)	7.70	8.81	1.11	8.32	0.27	3.25
ESP (%)	7.41	17.80	10.39	12.01	3.07	25.64
$CaCO_3$ (%)	7.31	51.19	43.88	28.19	8.77	31.12
CEC ($cmole^+ kg^{-1}$)	1.91	28.26	26.35	14.51	7.29	50.24
SOM (%)	0.02	0.98	0.96	0.34	0.31	91.18
Avail. N ($mg kg^{-1}$)	2.30	88.8	86.5	25.36	16.93	66.76
Avail. P ($mg kg^{-1}$)	1.82	11.06	9.24	4.90	1.90	38.78
Avail. K ($mg kg^{-1}$)	40.00	920.00	880.00	213.24	156.16	73.23

The soil bulk density had an average value of 1.41 Mg/m^3, with a range of 1.34 to 1.75 Mg/m^3. The wilting point, field capacity and available water contents were very low. Regarding the salinity and sodocity, the soils varied from slightly saline to very highly saline (ECe) and from low to moderately the sodic (ESP). The soil organic matter content ranged from very low to low (<1.0%) according to Landon (1984). Moreover, these soils differed from moderate to very high calcareous (7.31 to 51.19%). The CEC ranged from 1.91 to 28.26 $cmol^+/kg$ soil with an average of 14.51 $cmol^+/kg$. The dominant soluble basic cations were in the descending order of Na+, Ca^{+2}, Mg^{+2} and K^+, The exchangeable sodium percentage ranged from 7.41 to 17.80% with an average of 12.01%. Regarding the nutrients status of the soils, the available N and P were low, while the available K varied from low to high. Similar results were reported on the study area (wadi Qena) by Awad (1996), Abd El-Maksoud *et al.* (2000), Ali *et al.* (2006), Elewia *et al.* (2006), Moursy (2015) and Moursy *et al.* (2020 a & b).

2. Land Capability Evaluation

a- Current capability:

The land capability assessment is an important step to determine the agricultural capability of different soil profiles of the study area. The weighted means of some soil characteristics of each profile were used as input data for Modified Storie Index (O'Geen *et al.*, 2008).

The quantitative estimation of environmental conditions and soil properties such as soil profile depth, gravel content by volume, texture grade, slope, soil reaction (pH), ECe and SARe were used for the numerical land evaluation of the modified storie index. The investigated soil profiles were placed into classes according to their calculated capability indices. The results indicated that the current capability classes of the study area were good (grade 2), fair (grade 3), poor (grade 4) and non-agricultural (grade 5) due to some limiting factors (Table 5). The results also show that 1322.8 feddans which constitute about 8.94% of the evaluated area were good (grade 2) for agricultural use. However, 6516.4 feddans (44.04%) of this area were considered fair (grade 3) for agricultural use and 5133.4 feddans (38.75%) of the total area were considered poor (grade 4) and 1223.3 feddans (8.27%) were considered non-agricultural (grade 5) which had strong limitations and they are unsuitable for growing crops (Table 5).

Therefore, according to the modified storie index, the area that had the fair class (grade 3) was represented by soil profile numbers 30, 35, 40, 41 and 45. The essential limiting factors of this area were texture, soil salinity, sodium adsorption ratio (SARe) and gravels. However, the area that showed the poor class (grade 4), was referred by soil profile numbers 2, 4, 10, 15, 16, 17, 19, 21, 22, 27, 33, 39, 43 and 46. The soils of this class had limitations that require special management practices such as proper fertilization and management associated with intensive leaching can improve the soil suitability for various crops under consideration and/or severely restrict the growth of most crops. The principal limiting factors of these soils were the gravel content, sodium adsorption ratio, salinity, and coarse texture (Table 5). Therefore, with good management practices, these soils could be improved to be good or fair. The area that was considered as non-agricultural (grade 5), was described by soil profiles numbers 1, 3, 5, 6, 7, 8, 9, 11, 12, 13, 14, 18, 20, 23, 24, 25, 26, 28, 29, 31, 32, 34, 36, 37, 38, 42, 44,47, 48 and 49. The major limiting factors of these soils were the gravel content, sodium adsorption ratio, salinity, $CaCO_3$ content, texture grade slope grade and soil depth.

Also, the limiting factors of the study area such as salinity, nutrient availability and sodium adsorption could be corrected with time, while other factors such as texture grade, gravel content, soil depth, slope grade and $CaCO_3$ content are difficult to be corrected i.e. they are considered economically not correctable.

b- Potential land capability

Some of the limiting factors that prevail in the study area can be mitigated or improved by applying appropriate soil management practices, resulting in improving its current land capability to be potentially capable (Table 5). These soil management practices include:

1- Leaching the soil salts using a good water quality through the surface irrigation.
2- Applying organic fertilizers to improve the CEC and nutrient availability of the soil.
3- Using modern irrigation systems and reducing the irrigation periods to avoid salt accumulation and the formation of soil crust in the calcareous soils.

Table 5. Current and potential capability rating indices, grade and classes of the study area according to the modified storie index (O'Geen *et al.*, 2008).

Current capability				Potential capability			
Rating index (%)	Grade and class	Area		Rating index (Ci %)	Grade and class	area	
		fed.	%			fed.	%
80-100	Grade 1 (Excellent)	-	-	80-100	Grade 1 (Excellent)	-	-
60-79	Grade 2 (Good)	-	-	60-79	Grade (Good)	-	-
40-59	Grade 3 (Fair)	1322.8	8.94	40-59	Grade 3 (Fair)	3624.01	24.49
20-39	Grade 4 (Poor)	6516.2	44.04	20-39	Grade 4 (Poor)	9966.39	67.35
<20	Grade 5 (Non agric. suitable)	6958.9	47.02	<20	Grade 5 (Non agric. suitable)	1207.51	8.16
Total area		14797.9	100			14797.9	100

After applying these management practices, the agricultural land capability of the study area could be improved resulting in 3624.01 feddans (24.49%) to give a fair class and 9966.39 feddans (67.35%) to show a poor class (Table 5). Also, Moursy *et al*. (2020a) found that the soils of Eastern Sohag ranged between poor to fair capable. On the other hand, the area that is non-agricultural suitable will be reduced to 1207.51 feddans representing 8.16% of the study.

3- Land Suitability Evaluation:

The applied system of land evaluation program (ASLE) is used to assess the soil suitability of the study area for specific types of crops according to Ismail and Morsi (2001).

The soil properties that were used for estimating the suitability index for various crops were climate, slope, soil texture, drainage (Moursy *et al.,* 2020a, and field observation**)**, soil profile depth, calcium carbonate content, soil pH, gypsum content, soil salinity and sodocity.

The results showed that the soils under study had a good potential to grow crops under irrigation, provided that the water requirements are met. The ASLE program was applied to determine the land suitability of the studied soils for 25 growing crops which were classified into three categories as follow:

1- Field and forage crops (wheat, barley, faba bean, sugar beet, sunflower, rice, maize, soybean, peanut, cotton, alfalfa and sorghum).

2- Vegetable crops (onion, cabbage, watermelon, pea, pepper, tomato and potato).

3- Fruit trees (grape, olive, apple, pear, fig and date palm).

These crops are mostly suitable for arid and semi-arid soils. The results showed that the land suitability of the study area had a wide range of suitability, namely high suitable (SI), suitable (S2) moderately suitable (S3), marginally suitable (S4), currently not suitable (NS1) and permanently not suitable (NS2), for the selected crops. The suitability for the most used crops varied from suitable (S2) to not suitable (NS1) due to different soil factors (Table 6).

The highly suitable class (S1) was only recorded for olive that occupied an area of 3.5% of the total study area (Table 6).

Moreover, the suitable class (S2) was registered for wheat, barley, faba bean, sugar beet, sunflower, peanut, alfalfa, pea, potato, pipper, watermelon, grape, olive, apple, pea, fig and date palm which they planted an area of 17.39, 20.2, 3.8, 20.0, 21.7, 0.8, 11.3, 4, 3.2, 24, 18.7, 16.3, 36.9, 10.9, 1.8, 23 and 43.5% of the total studied area, respectively.

However, the moderately suitable class (S3) was enrolled for wheat, barley, faba bean, sugar beet, sunflower, maize, soybean, peanut, alfalfa and sorghum, pea, potato, pepper, watermelon, grape, olive, apple, pear, fig and date palm which they represented an area of 48.03, 49.2, 35.7, 47.4, 44.0, 50.1, 25.1, 11.9, 40.2 and 35.5, 16.0, 35.9, 21.7, 44.6, 27.3, 19.5, 53.7, 49.8 and 29.3% of the total studied area, respectively. In addition, the marginally suitable class (S4) was set down for wheat, barley, faba bean, sugar beet, sunflower, maize, soybean, peanut, sorghum, tomato, pepper, watermelon, olive, fig and date palm which they occupied an area of 5.12, 4.80, 60.50, 4.70, 6.30, 10.20, 1.70, 1.4, 5.80, 10.50, 23.20, 9.50, 24.20, 24.90, 15.40 and 19.00%, respectively. On the other hand, the currently not suitable class (NS1) was listed for wheat, barley, sugar beet, sunflower, rice, maize, soybean, peanut, cotton, alfalfa, sorghum, onion, cabbage, pea, potato, tomato, pepper, watermelon, grape, olive, apple, pear, fig and date palm that they cultivated an area of 29.46, 25.9, 27.9, 28.0, 4.3, 59.5, 73.2, 45.7, 5.2, 42.7, 54.0, 7.6, 14.9, 75.6, 44.8, 43.4, 30.6, 35.4, 28.1, 7.1, 65.6, 44.5, 11.8 and 8.2% of the total study area, respectively. Meanwhile, the permanently not suitable class (NS2) was put down for rice, peanut, cotton, onion, cabbage, potato and tomato, which they showed an area of 95.7, 40.2, 94.8, 92.4, 85.1, 36.0 and 33.4 of the total investigated area, respectively.

Table 6. Land suitability classes and their area percentages for different crops in the middle part of Wadi Qena, East Desert, Egypt (according to Ismail and Morsi, 2001).

Crop	Land suitability class					
	S1	S2	S3	S4	NS1	NS2
A- Field and forage crops						
Wheat	0	17.39	48.03	5.12	29.46	0
Barley	0	20.20	49.20	4.80	25.80	0
Faba bean	0	3.80	35.70	60.50	0	0
Sugar beet	0	20.00	47.40	4.70	27.90	0
Sunflower	0	21.7	44.0	6.30	28.00	0
Rice	0	0	0	0	4.30	95.70
Maize	0	0	50.10	10.20	59.70	0
Soybean	0	0	25.10	1.70	73.20	0
Peanut	0	0.80	11.90	1.40	45.70	40.20
Cotton	0	0	0	0	5.20	94.80
Alfalfa	0	11.30	40.20	5.80	42.70	0
Sorghum	0	0	35.50	10.50	54.00	0
B- Vegetable crops and fruit trees						
Onion	0	0	0	0	7.60	92.40
Cabbage	0	0	0	0	14.90	85.10
Pea	0	4.00	20.40	0	75.60	0
Potato	0	3.20	16.00	0	44.80	36.00
Tomato	0	0	0	23.20	43.40	33.40
Pepper	0	24.00	35.90	9.50	30.60	0
Watermelon	0	18.70	21.70	24.20	35.40	0
Grape	0	16.30	55.60	0	28.10	0
Olive	3.50	36.90	27.30	24.90	7.40	0
Apple	0	10.90	19.50	0	69.60	0
Pear	0	1.80	53.70	0	44.50	0
Fig	0	23.00	49.80	15.40	11.80	0
Date palm	0	43.50	29.30	19.00	8.20	0

S1= High suitable, S2= Suitable, S3= Moderate suitable, S4- marginally suitable,
NS1= Currently not suitable and NS2= Permanently not suitable

Moursy *et al.* (2020a), using the ALES model, found that the soils of Wadi Qena differed from non-suitable (N1) to moderately suitable (S2) for growing some evaluated crops (wheat, maize, alfalfa, tomato, olives and mango). Marginally suitable (S3) for wheat, maize and olive crops, while they were moderately suitable (S2) for alfalfa crop. However, all these soils were non-suitable (N1) for growing tomato. They concluded that, the limitations, of these soils of Wadi Qena ranged from slight to moderate. The limitations of this area were soil texture, salinity and organic matter content, could be enhanced through the addition of clay and organic materials. Similar results were also declared by Belal *et al.* (2014), who found that wheat was highly to moderately suitable in some agricultural expansion areas in the Eastern desert of Egypt, while cotton was high to permanent not suitable for different development. However, the suitability of maize was similar to the cotton crop. They pointed out potato ranged from moderately high to permanent not suitable and tomatoes varied from high to permanent not suitable. Also, citrus fruits were mainly permanent not suitable for growing in different development area. On the other hand, the date palm and olive trees differed from high to permanent not suitable.

Conclusion

The descriptive statistical analysis of the soil properties of the study area showed that the soil salinity, soil alkalinity, organic matter content, available nutrients (N, P and K) and $CaCO_3$ content had high variability which reflected the high variation among the soil profiles of the study area.

The soils of the study area ranged between poor and fair for agricultural use. They also varied from suitable to non-agricultural suitable for growing some field, vegetables, forage crops and fruits.

The most suitable crops to grow in the study area are wheat, barley, sunflower, date palm, olive, fig, grape, alfalfa, sorghum and bear. The general dominant limiting factors that affect land capability and crop suitability are the coarse soil texture, sol salinity, sodicity, organic matter content and nutrient availability.

This study presents a valuable guide for decision-makers and farmers to make their choices for best agricultural management, prevent land desertification and help land reclamation projects in Wadi Qena, Eastern desert. It also displays kinds of crops that should be grow on such desert soils.

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الجدارة الإنتاجية لأراضي الجزء الأوسط من وادي قنا، الصحراء الشرقية، مصر ومدي ملائمتها لزراعة المحاصيل

محمود كمال كامل عطيه، محسن عبد المنعم جامع، محمد علي الدسوقي زيدان، صلاح حسانين عبدالعزيز
قسم الأراضي والمياه، كلية الزراعة، جامعة أسيوط

الملخص

الزراعة المستدامة هى الهدف الرئيسى من تقييم الأراضي وتعتبر منطقة وادي قنا – الصحراء الشرقية – من أهم مناطق الاستصلاح المستهدفة للامتداد الزراعى الأفقي لمقابلة الزيادة المطردة فى السكان.

وقد حاولت هذه الدراسة بحث أفضل استخدام للأراضي في الزراعة لإضافة مساحة زراعية جديدة في الجزء الأوسط من وادي قنا – الصحراء الشرقية وذلك استناداً إلي الخصائص والصفات المميزة للتربة.

وتهدف هذه الدراسة إلي تقييم الجدارة الإنتاجية لأراضي الجزء الأوسط من وادي قنا – الصحراء الشرقية ومدى ملائمتها لزراعة المحاصيل.

أجريت هذه الدراسة خلال شهر فبراير ٢٠١٧ حيث تم تجميع العينات الممثلة للتربة لإجراء التحليلات اللازمة لذلك حيث تم اختيار ٤٩ قطاعاً أرضياً تمثل مختلف أنواع التربة في الجزء الأوسط من وادي قنا. تم حفر هذه القطاعات إلي العمق المناسب وفقاً لطبيعة التربة ما لم يعوقها قاع صخرى أو منسوب مائي – كما تم تقييم الجدارة الإنتاجية لهذه الأراضي باستخدام نظامين من نظم التقييم وهما برنامج ASLE ونظام Modified storie index بينما تم تقييم ملائمة هذه الأراضي لزراعة المحاصيل المختلفة باستخدام برنامج ASLE.

وقد تبين من قيم خواص التربة المميزة وجود تباين عالي في هذه الخواص حيث تراوحت قيم التوصل الكهربي لمستخلص عجينة التربة المشبعة من ٠,٨٣ إلي ١٨٧,٦ ديسيمنز/م ونسبة الصوديوم المتبادل ٧,٤١ إلي ١٧,٨٠%، والمحتوي الكلي للتربة من كربونات الكالسيوم من ٧,٣١ إلي ٥١,١٩% وتفاعل التربة من ٧,٧ إلي ٨,٨١ ومحتواها من الصورة الميسرة للنيتروجين والفوسفور والبوتاسيوم يتراوح من ٢٣ إلي ٨٨٨، من ١,٨٢ إلي ١١,٠٦ ، من ٤٠ إلي ٩٢٠ ملجم/كجم علي التوالي وعمق قطاع التربة من ٥٠ إلي أكبر من ١٥٠ سم.

تتراوح قيم التوصيل الهيدروليكي في هذه الاراضي بين ٢,٩٢ ال ٣٨,٠٠ سم/ ساعه وتتراوح قيم السعة الحقلية ونقطة الذبول والماء الميسر لعينات التربة المدروسة بين ١٠،٥- ٢٦,٥٤%، ٤,٣٦- ١٢,٦١% و ٤,٩٤- ١٨,١٣% بمتوسطات ١٧,٠٣ ، ٧,٦٣ و ٩,٤٠% على التوالي.

أظهرت النتائج الخاصة بالجدارة الإنتاجية لأراضي منطقة الدراسة طبقاً لدليل أستوري معتدلة Fair (درجة ثالثة) بمساحة ١٣٢٢,٨ فدان بنسبة ٨,٩٤%، فقيرة Poor (درجة رابعة) بمساحة ٦٥١٦,٢ فدان بنسبة ٤٤,٤% وغير مناسبة Non-agriculture للاستخدام الزراعي بمساحة ٦٩٥٨,٩ فدان بنسبة ٤٧,٠٣% من إجمالي مساحة أراضي الجزء الأوسط لوادي قنا تحت الدراسة وفقاً للعوامل المحددة وذلك طبقاً لدليل أستوري Modified Storie Index.

وكانت الجدارة الإنتاجية لأراضي منطقة الدراسة وفقاً لبرنامج ASLE فقيرة Poor (درجة رابعة) بمساحة ١٠٠٤٣,٦ فدان بنسبة ٦٧,٨٧% من إجمالي مساحة منطقة الدراسة، وفقيرة جداً Very poor (درجة خامسة) بمساحة ٦٣٦٦,٦ فدان بنسبة ٢٤,٥٧%، وغير

صالحة للاستخدام الزراعي Non-agriculture Suitable (درجة سادسة) بمساحة ١١١٨,٦ فدان بنسبة ٧,٥٦% حسب العوامل المحددة لذلك.

لتحسين القدرة الإنتاجية المستقبلية لهذه المنطقة فإنه يوصي بتنفيذ إجراءات عملية متعلقة بإدارة خدمة التربة وذلك لتحسين خصائص التربة التي تتسم بقابليتها للعلاج وبالتالي يمكن الوصول إلي الإنتاجية الكامنة (المستقبلية) لتصبح معتدلة (درجة ثالثة) ولكن بمساحة ٣٦٢٤,٠١ فدان بنسبة ٢٤,٤٩% أي بزيادة قدرها ٢٣٠١,٢١ فدان بنسبة ١٥,٥٥% عن مساحة الجدرة الإنتاجية المعتدلة لأراضي المنطقة بحالتها الطبيعية وحوالي ٩٩٦٦,٣٩ فدان بنسبة ٦٧,٣٥% من إجمالي مساحة أراضي منطقة الدراسة وتعتبر فقيرة بزيادة قدرها ٣٠٠٧,٤٩ فدان بنسبة تعادل ٢٣,٣١% عن مثيلتها بدون إجراء أي تحسينات لخصائصها وحوال ٢٠٧,٥١ فدان بنسبة ٨,١٦% من إجمالي أراضي منطقة الدراسة تعتبر غير مناسبة للاستخدام الزراعي بنقص يقدر بحوالي ٥٧٥١,٣٩ فدان بنسبة ٣٨,٨٦% وهذا النقص في مساحة هذه الفئة غير الصالحة للزراعة إلي تحسين خصائص وصفات هذه المساحات وتحولها من أراضي غير صالحة إلي أراضي فقيرة ومعتدلة للاستخدام الزراعي.

وقد دلت نتائج تحليل درجة ملائمة استخدام الأرض للزراعة أن زراعة محاصيل القمح ، الشعير، الذرة الشامية، البرسيم الحجازي، الذرة العلفية، البطاطس، البسلة، دوار الشمس، بنجر السكر، الفول السوداني، البطيخ، العنب، التين، التفاح، الكمثري، الزيتون والنخيل حيث كانت أفضل المحاصيل ملائمة للزراعة المروية في منطقة الدراسة. وقد وجد أن العوامل الرئيسية المحددة لاستخدام أراضي منطقة الدراسة تحت الزراعة المروية والتي تؤثر بالسلب علي ملائمة الأرض لزراعة المحاصيل المختلفة هي الملوحة المرتفعة، محتوي كربونات الكالسيوم المرتفع، نسبة الصوديوم المرتفع، قوام التربة الخشن والفقر في محتوي النيتروجين والفوسفور ومحتواها من المادة العضوية– لذا يمكن تحسين هذه المحددات لتحقيق الاستخدام الزراعي المستدام لهذه الأراضي بإتباع ما يلي:

١– إدارة جيدة لهذه الأراضي خاصة في عمليات الخدمة وإتباع دورة زراعية مناسبة.

٢– إضافة المادة العضوية بصفة مستمرة لتحسين صفات وخواص هذه الأراضي.

٣– استخدام بعض محسنات التربة والأسمدة ذات التأثير الحامضي.

٤– إتباع نظم للري الحديث مع غسيل الأملاح وتقصير فترات الري.

وذلك لتحسين خصائص التربة وصفاتها التي تتسم بقابليتها للعلاج وبالتالي يمكن الوصول إلي الإنتاجية الكامنة (المستقبلية) لأراضي الجزء الأوسط من وادي قنا بالصحراء الشرقية.

تعتبر مخرجات هذه الدراسة البحثية بمثابة مصدر ذو قيمة تطبيقية للهيئات الحكومية المهتمة بمشاريع استصلاح الأراضي والتي تأخذ أيضاً في اعتبارها التنمية الزراعية المستدامة في الصحراء الشرقية بصفة عامة ووادي قنا بصفة خاصة.

الكلمات الدالة: *القدرة الإنتاجية للأراضي – القدرة الكامنة – تقييم الأراضي - الزراعة المستدامة – وادي قنا – الصحراء الشرقية - مصر.*