Evaluation of Wadi Hudein Delta's Soils, Al-Shalatien, Southeastern Egypt

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ABSTRACT

Halaieb – El-Shalatien triangle could be considered one of the most promising areas for agrarian activities at south of Egypt. Land use planning is aggressively needed to enhance agricultural utilization in the area. The present work aimed at identifying land use limitations which affect negatively the agricultural production at Wadi Hudien, which is considered the widest drainage basin at that region. The studied area was selected to represent Delta of Wadi Hudien over 34000 feddan at Al-Shalatien. DEM and slope maps were generated using GIS processing. Studied area is an almost flat wide plain, classified into four landforms namely from east to west; coastal wet Sabkha, Wadi Terraces and Mountainous down slops in addition to Wadi channel. Soil survey was undertaken using an OLI Landsat image where 37 soil profiles were dug representing whole landforms. Soil samples were collected and analyzed by standard technique. Six soil mapping units were differentiated in accordance to variations in soil depth, texture, gravels and salinity. They are dominated by slightly saline deep gravelly sandy soils (29%) followed by slightly saline deep sandy soils (28%) which are classified as *Typic Torripsamments*. Storie index (2008) was applied and evaluated the soils under investigation as poor over 91.65% of the total area, whereas the rest of the area was classified as non agricultural. As the erosion and drainage affect negatively the soil ranking, they were avoided based on expected improvements. Thus, three land capability classes were detected; fair, poor and non agricultural over 10.36, 84.93 and 4.71% of the entire terrain, respectively. Moreover, results revealed that soils of Wadi Hudien are relatively suitable for sustainable agriculture over 95% of the area under proper management of salt affected soils and flash flooding. The main limitations for land use were identified over some areas as rock exposures, shallowness of soil profile, extreme salinity in addition to severe climatic conditions. Soils of Wadi Hudien were found to be suitable for producing barely, sorghum, wheat, olives, alfalfa, maize, sunflower and citrus. Barely and Sorghum were assessed as the most optimum crops as they got 100% of suitability index at soil unit SMU02, whereas their indices ranged between 91.6 and 97.2% at soil units SMU01, SMU03 and SMU04. In addition to achieved land suitability for producing different crops, attention must be paid to protect valuable fauna and flora, and marine natural resources as animal fodders. Current investigation emphasized that soils of Wadi Hudien delta are suitable for agricultural production under suitable management of flash floods as main water resources in this region.

Key words: Land Evaluation, Land Use, Wadi Hudien, El-Shalatien, Southeastern Egypt.

INTRODUCTION

The integrated strategy of agricultural development in Egypt is planned depending on implementing major projects at desert regions, i.e. South of valley, North of Sinai, and The Golden Triangle at Red Sea coast. One of the mega sustainable development projects is implemented in Halaieb - Al-Shalatien region over about 35000 km^2 at South of Egypt. That region is characterized by a narrow coastal strip and series of mountainous landscapes that extend parallel to the Red Sea. The mountainous region has variant elevations that increase westward to reach more than 1900 m above sea level. It is dissected by numerous wadis like Al-Rahba, Di-ib, and Hudein. (Beshay *et. al.*, 2002).

The regional soil survey of this area conducted by Abdel Rahman (2004) revealed that the most suitable locations for agricultural development are located in the coastal zone. It consists of a number of deltas, plains and wadi formations. The Egyptian administration aimed at spreading agrarian activities of field and forage crops in these areas through irrigation by groundwater.

Some soils of Halaieb-El-Shalatien region were classified after Abdel Rahman (1998) at subgroup level as *Torriorthents*, *Torripsamments*, and *Quartizipsamments*, while Awad (1996) classified them as *Torripsamments* and *Torrifluvents*. Abdel Rahman (1997) investigated salt affected soils in the coastal ecosystem of the Red Sea to characterize and map soil types in the alluvial fans of El-Shalatien area. Gaber *et. al.* (1999) studied the soil resources at El-Shalatien area as affected by slopes and parent material. Buttros (2002) identified different soil types and their capability classes at some areas of El-Shalatien-Halaieb regions. Meanwhile, Darwish (2000) pointed out the effect of soil erosion and its relation to some soil physical properties at El-Shalatien.

Abd El-Rahman (1999) stated that dominant sever climate conditions either during summer or winter in addition to low quality of available ground water are the main limiting factors at Halaib region. Moreover, plantation of wadis, fans and flood plain soils help greatly in controlling erosion and improving moisture content as a result of reducing run-off and losses of nutrients and fine materials. Soil, water and environment research institute staff (1994) reported that Al-Shalatien-Halaieb region depends mainly on rainfall, hence, aggregational landforms that receive runoff water from the surroundings are the most promising areas for agricultural development.

Desert Research Center Staff (1994) reported that based on the morpho-pedological investigations, a great portion of Al-Shalatien-Halaib region has agricultural potentialities with special management practices. Moreover, some areas at the region found to be suitable for certain crops namely; sorghum, watermelon, perel milt and cucumber. Land suitability ranged between the second and the sixth grades. Desert Research Center Staff (1997) concluded that although existing of severe limitations concerning water and soils resources at Halaib triangle the natural association of desert plants i.e. medicine, aromatic and forage plants, have an amazing adaptation with dominant environmental conditions.

In this context, Wadi Hudein with its promising Delta represents a model for the agricultural expansion in this region. Soils of Wadi Hudein have to be checked carefully through a well designed investigation to insure their relevancy for cultivation regarding their main characteristics like soil depth, texture, salinity and permeability. Soils have to be evaluated using land capability assessment based on identifying soil limiting factors.

Consequently, the current work aimed at recognizing the different soil types of Wadi Hudein delta, in addition to assess their potentialities in terms of land capability and suitability for specific uses.

PHYSIOGRAPHIC FEATURES OF THE STUDY AREA

Wadi Hudein basin extends at Al-Shalatien area from the Red Sea Mountains to the eastern coastal line at the southern-east of Egypt. Selected area of Wadi Hudein Delta is located between 35° 21' 54.1" – 35° 37' 25.8" E and 23° 01' 12.33" – 23° 08' 58.05" N occupying an area of about 143 km^2 (Map 1).

Table (1) summarizes the averaged metrological data at El-Shalatien area over 25 years between 1990 and 2015 according to the Egyptian Meteorological Authority (2015). The area under consideration is predominated by hot and moist climate in the eastern part, whereas, the climate is arid and associated with winter thunder storms in the adjacent mountainous area to the west causing flash floods. Cold weather is apt to prevail for few weeks in January and February. Wind velocity is fairly constant allover the year and range between 10.8 and 14.6 km/h with north and north-western dominant direction. Dust storms are frequent and associated with El-Khamasine sand storm during spring and early summer seasons. Mean temperature is about 31 ^oC in summer and 20 ^oC in winter.

Many investigations were carried out to illustrate the lithological successions of Wadi Hudein basin i.e. Ghanem (1972), Ramadan (1994), Aglan (2001) and Egyptian Geological Survey (1992). It has been concluded that Precambrian basement rocks forms about 80 % of the basin surface. Cretaceous Nubian sandstone is dominated the upper portions of the basin area (the western part), while Quaternary and Holocene sediments cover the lower areas (the eastern portion) between the Red Sea Mountains and the coastal line. During these recent eras, the investigated area at Wadi Hudien delta received weathered materials of gravels, sand, and rock fragments and form an alluvial downwash plain as affected by water action, in addition to the contribution of wind blown sand deposits.

Geomorphologically, Aglan (2001) classified Hudein basin into five landforms as follows: (1) Basement rocks of the Red Sea Mountains which cover about 80 % of the total area. Igneous and metamorphic rocks are dominated this landform which is considered the main source of the groundwater due to existing faults. (2) Sandy plateau which located at the eastern portion of Ababda Plateau. It includes many elevated mountains, i.e. Abric (697 m A.S.L), Hudein (716 m A.S.L) and Al-Duf (731m A.S.L). (3) Low inner plains which penetrates the plateau and the mountainous areas. (4) Volcanic hills of basaltic construction which spread between the basement rocks and the piedmont plain. (5) Piedmont and coastal plain, in which the area under study was extracted. It is located between the eastern coastal shoreline and the western mountains. This plain width is varying from 1 to 10 km covering an area of about 143 km^2. Eroded materials, derived from mountainous area by water action are dominated these plain sediments.

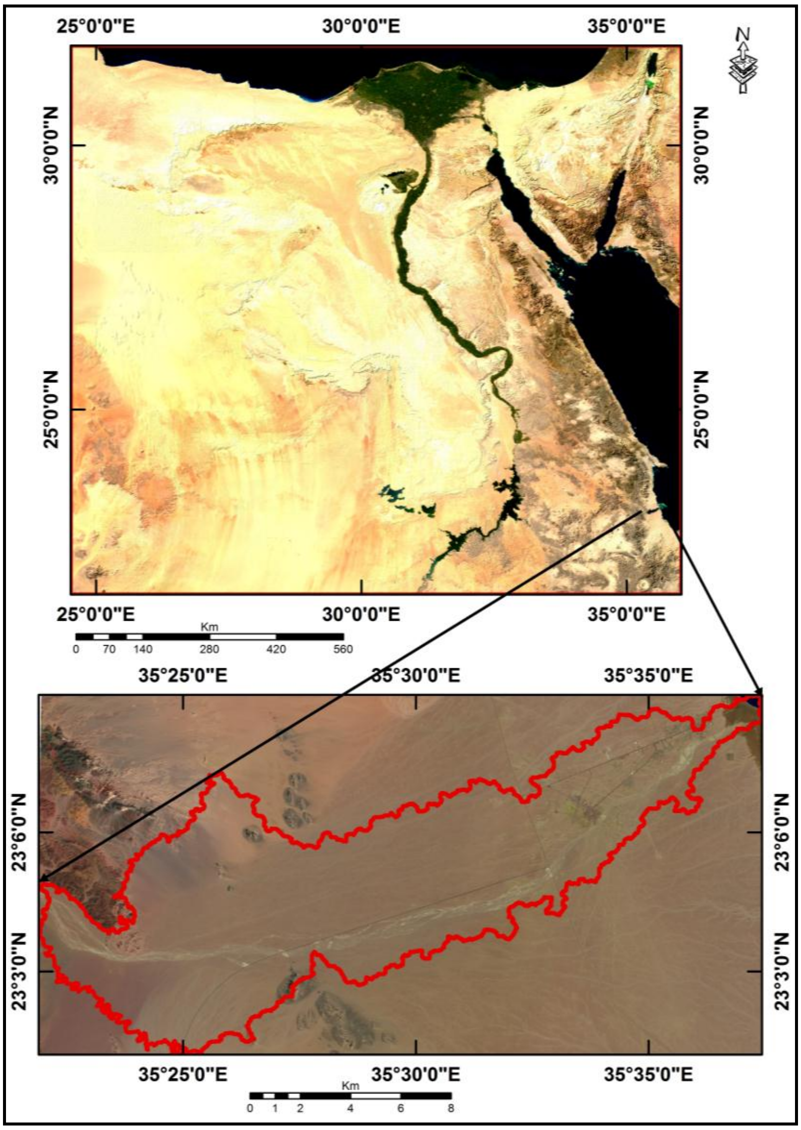
Hydrological aspects of the area were investigated by few studies, mainly focused on the geology and mineral resources. However, Zaghloul (1996) and El-Rakaiby *et. al.* (1996) explored the water resources of the area through geological and hydrological investigations. They concluded that groundwater resources can be present in four types of rocks, namely; fractured basement, Nubian cretaceous sandstone, Miocene limestone, and Wadi deposits. The ground water of the fractured basement rock would have the best water quality of the four types. The groundwater of the Delta and Wadi regions are saline to highly saline (5000-17000 ppm) due to sea water intrusion and the presence of old saline sediments and evaporates.

The discharge is limited and depends on the precipitation in the mountainous region. Hammad (1996) concluded that some wadis of El-Shalatien basin have high potentiality of water run off, which must be controlled by construction of dams and/or dykes. Moreover, the morphometric analysis of Wadi Hudien estimated the average of flood water amount as 808.2 million m^3/year.

MATERIALS AND METHODS

1- GIS and RS Processing

A landsat 8 OLI image captured in 2015 was used to explore the ground surface using ERDAS Imagine 9.3 software (2010). Observation sites were distributed in a regular grid system (Map 2) using Arc-GIS program (ESRI, 2010). Designed regular grid system for soil sampling represents whole apparent differences achieved into the classified image.



Map 1: Location of the study area at Wadi Hudien

Table 1: Averaged metrological data of El-Shalatien area from 1990 to 2015.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
High temp °C	25.5	26.5	28.3	31.7	34.7	36.5	37.4	37.4	36.1	33.9	30.4	26.8	32.1
Daily temp.°C	19.7	20.4	22.2	25.3	28.5	30	31.3	31.5	30.2	28.1	24.7	21.3	26.1
Low temp °C	14	14.3	16.1	18.9	22.4	23.6	25.3	25.6	24.4	22.3	19.1	15.8	20.15
Rainfall, mm	0	0	1	1	1	0	0	0	0	2	9	2	16
Wind km hr^{-1}	13.2	12.8	13.6	14.2	12.0	11.4	10.8	10.8	11.6	12.2	13.7	14.6	12.6
Relative Hum. %	27.4	28.5	30.9	39.7	44.1	45.2	52.4	55.8	46.9	41.0	34.8	32.4	39.9

Contour line and spot heights were extracted from four 1:50,000 topographic maps to model the area elevations which ease to delineate micro landforms of the piedmont and coastal plains at wadi Hudien. Further, the field checks and laboratory study were integrated to the image visual interpretation which permits a detailed delineation of the dominated landforms in the study area.

2- Field Work

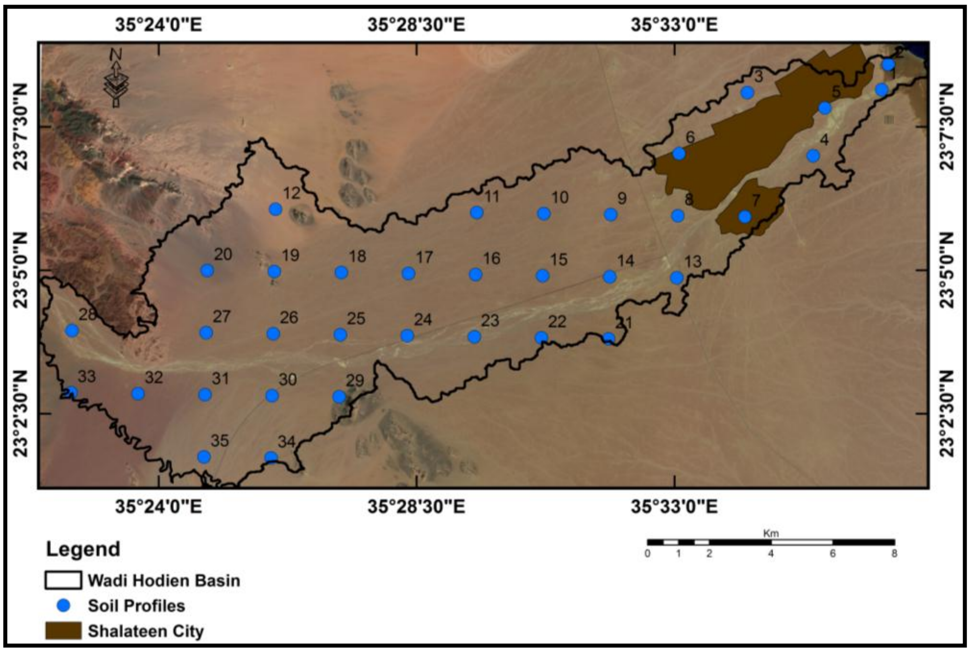
Detailed morphological description was carried out at each soil profile location for surface features on the basis of FAO (2006) guidelines for soil description. It includes surface topography, natural vegetation cover, nature of desert pavement and current land use. A total of 37 Soil profiles were dug to 1.5 meter unless preventing by bedrock or groundwater. Full pedo-morphological description was fulfilled for soil profile at each investigated location, including profile depth, layer thickness, soil texture, soil structure, color, compaction, consistency and secondary formations of lime, gypsum, salts, or ferrous oxides (FAO, 2006). Soil sampling was performed for further laboratory analyses. A total of 105 soil samples were collected representing the area under study.

3- Laboratory Analysis

Soil samples were air dried, crushed and sieved using 2 mm sieve. Then they were subjected to laboratory analyses as follows (1) Physical analyses according to USDA (2004) including: mechanical analysis (soil particle distribution) using dry sieving method for the fraction less than 2 mm, determination of gravel percentage for the fraction over 2 mm. (2) Chemical analyses based on USDA (2004) including: total soluble salts as indicated by electrical conductivity (EC) for the soil extract with ratio 1:1, pH was measured before extract filtration, and total calcium carbonate using Collin's Calcimater. (3) Fertility properties as total organic matter content to a depth of 50 cm using the loss-in-ignition method (Nelson and Sommers, 1996).

4- Land Evaluation

The current study used a revised Storie index (UCDAVIS, 2008) as a numerical method for land evaluation, in which multiple soil parameters are incorporated such as slope gradient, profile depth, soil texture, gravel content, soil reaction, soil salinity, drainage conditions, and erosion. This system classifies a given soil into one of five classes in relation to limitation severity as shown in Table (2). Land suitability classification was elaborated for some certain crops using an automated model. Land Use Suitability Evaluation Tool (LUSET) was applied according to Yen *et al.* (2006). This system classifies a given soil into one of four classes in relation to limitation severity (Table 3).



Map 2: Locations of soil profiles over representing image of Wadi Hudien Delta.

Table 2: Land capability classes according to revised Storie Index (2008)

Class	Definition	Rate %	Limitation severity
1	Excellent	80 - 100	No limitation
2	Good	60- 80	Slight limitation
3	Fair	40 - 60	Moderate limitation
4	Poor	10 - 40	Sever limitation
5	Non-agricultural	0 - 10	Very sever limitation

Table 3: Land suitability classes according to LUSET (2006)

Class	Definition	Rate %	Limitation severity
S1	Highly suitable	85 - 100	No limitation
S2	moderately suitable	60 - 85	Slight limitation
S3	marginally suitable	40 - 60	Moderate limitation
N	not suitable	0 - 40	Very sever limitation

RESULTS AND DISCUSION

1- Surface characteristics

Elevations of the study area are ranging between zero and 100 m above sea level (Map 3). Altitudes are gradually decreased eastward. Slope gradient were derived and found to be ranging from flat to 10 % (Map 4). Most of the area under consideration has gentle slopes (0 to 1 %), while moderate slopes (1-5 %) occur at the areas adjacent to the mountains. Very limited areas are having the higher slopes (5-10 %).

Soil surfaces at the studied observations are commonly covered by rock fragments. As being closer to the Red Sea Mountains to the west as the rock fragments become abundant and coarser. Natural vegetation and desert shrubs are sparsely diffused particularly at the eastern terraces of Wadi Hudein. *Acacia sp*. is the most dominant grown natural plant, while other species are scattering the wadi course. Hummocks are spreading the western locations of the basin area.

Based on Digital Elevation Model and slope maps, the area under study could be considered as a great plain extends from the Red Sea shoreline to the Red Sea Mountains. However, according to the visual interpretation of Landsat image, the study area is classified into four major landforms. They are sabkha, wadi channel, wadi terraces, and mountainous down slope (Map 5).

Achieved landforms were distinguished by their deposits that are loose, unconsolidated sediments, which have been eroded and reshaped by water action. The alluvium deposits cover from west to east along the study area representing most of wadi terraces and channel landforms. It is typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel. In some areas, the alluvial deposits are either mixed with colluvial deposits as remarked at the mountainous down slope or mixed with saline deposits as remarked at the sabkha area.

Colluvial deposits were moved down slope of the Red sea mountain due to gravitational forces (water action may play a role in movement initiation). Generally, colluvium is heterogeneous, unsorted material of all particle sizes (from boulders to sand) with relatively little abrasion to round particles. Consequently, it consists of very sharp, angular rock fragments accumulated at the base of steep slopes.

At Sabkha area, the alluvial deposits are mixed up with saline deposits that are derived from the sea water intrusion. Under such depositional environment with high evaporation, the pore waters become highly concentrated and drawn towards the surface, causing the precipitation of evaporates *i.e.* halite, gypsum and anhydrite, with some authigenic minerals *i.e.* aragonite, calcite, and dolomite.

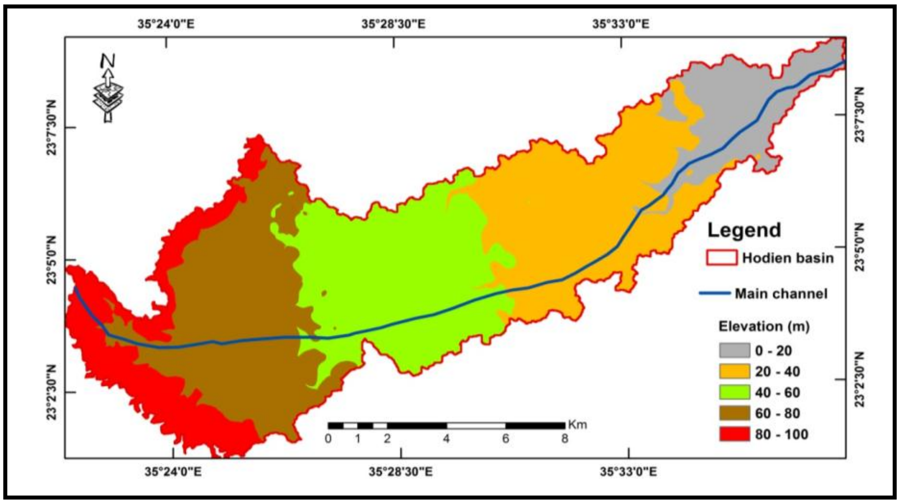
2- Soil characteristics

Based on analytical data along with field observations, soil properties will be discussed in terms of their intensity and spatial distribution. Morphologically, soil colors were widely varied either in dry or moist conditions from very pale brown to dark grayish brown. This could be attributed to the heterogeneity of dominant parent materials.

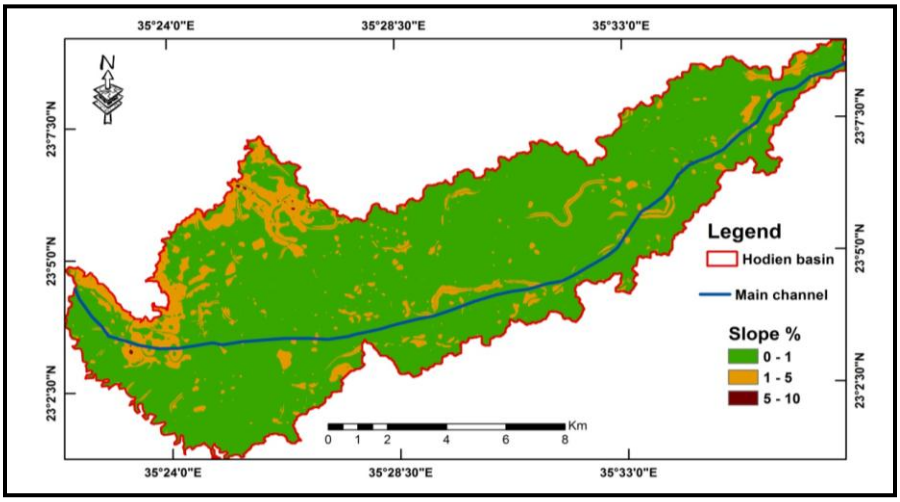
Soil profile depth is dominated by deep class over about 86.5% of the total study area (Table 4), while shallow depths are limited adjacent to the western mountains. However, deep soils (100-150 cm) have the predominance, except profile No. 3 which is considered moderately deep (50-100 cm) and profiles Nos. 12, 20, 33, and 34 are classified as shallow (25-50 cm) as shown in map (6A).

Soils of the area under consideration have sandy texture classes which ranged from very fine sand to coarse sand. However, the coarse sand represents the most dominant texture over whole studied profiles (Table 4 and Map 6B).

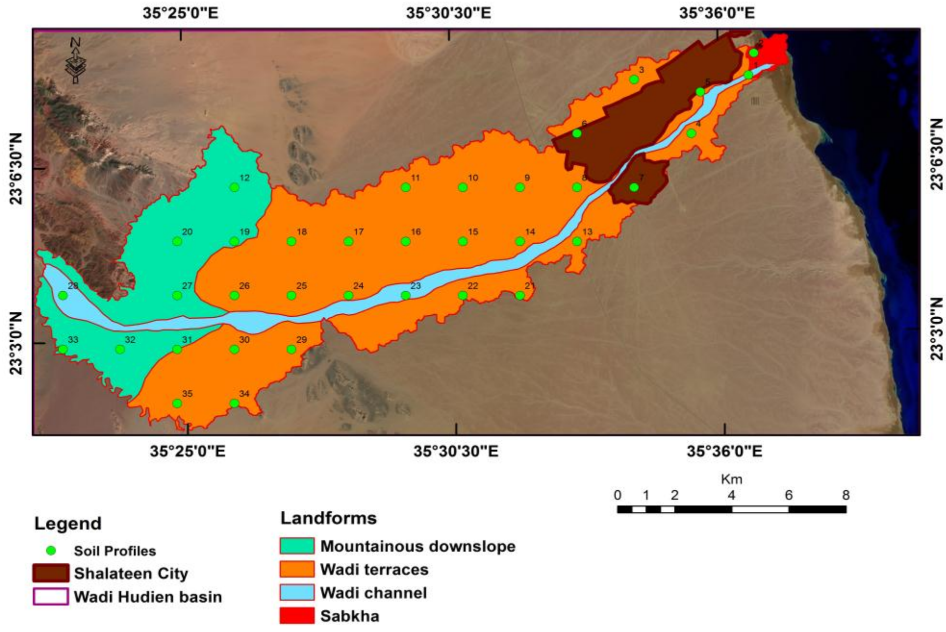
On the other hand, soils of the area are structureless and characterized by single grains structure or irregular bodies with no stickiness and plasticity. Field investigations revealed that gravels decrease regularly as going far from hilly location towards the main wadi course.



Map 3: DEM of the study area at Wadi Hudien Delta.



Map 4: Slope gradient of the study area at Wadi Hudien Delta.



Map 5: Main landforms of the study area at Wadi Hudien Delta.

In general, gravel content varies widely among different locations which emphasized by analytical data that gravel percentage range from zero to 75 % throughout soil profiles (Table 4 and Map 6C). Volumetrically, gravels vary from very fine to coarse rock grits which spread diffusely adjacent to mountainous areas.

Wide range of pH values were recorded, while the majority was highly alkaline ones. However, soil pH data could be classified into four classes (Table 4) according to Soil Survey Division Staff (1993), neutral reaction (7.0-7.3), slightly reaction (7.3-7.8), moderately alkaline reaction (7.8-8.4) and strongly alkaline reaction (8.4-9.0). Five soil salinity classes were achieved in the area under study; non saline (0-2 dS/m), slightly saline (2-4 dS/m), moderately saline (4-8 dS/m), strongly saline (8-16 dS/m), and extremely saline (over 16 dS/m). However, total dissolved salts varied widely from 0.11 to 85 dS/m (Table 4), where low saline soils occupy main wadi course and terraces, meanwhile strongly and extremely saline ones exist near either the coast or the mountainous area (Map 6D). Lime content ($CaCO_3$) varied within a narrow range, as calcium carbonate concentrations are ranged between zero and 7.9 % (Table 4). Based on lime content, soils could be classified into two classes, non-calcareous (0-2 %) with the predominance over the study area, and slightly calcareous (2-10 %) which exist sparsely over the investigated terrain.

Soil content of organic matter does not exceed 1 % over whole studied profiles (Table 4). This may be attributed to the highly decomposition rates of organic matter under hot arid climate as well the absence of any agrarian activity in the area. Such low organic matter is associated with dominant course texture, which reflect a poor fertility status in the study area regarding its macro and micronutrients.

3- Soil mapping units

Average weighted means were calculated for resultant soil data. A unique value was given for each investigated property to identify each soil profile. The averaging based on considering a weighted mean for each soil layer where high means were assigned as the layer is approaching the surface and associated to layers with larger thickness. Six soil mapping units were achieved according to detected differences in soil depth, texture, gravels and salinity (Table 5). The spatial distributions of these soil properties were interpolated (Map 6) and overlain to delineate soil units (Map 7).

Detected soil mapping units are dominated by slightly saline deep gravelly sandy soils (29%) followed by slightly saline deep sandy soils (28%) as indicated in table (5).

4- Land Evaluation

The delta of Wadi Hudein has different soil types with several characteristics regarding their physiographic, physical, and chemical properties. These types represent different degree of potentialities from agricultural point of view. One of the most important layers of soil information is its capability which is required during decision making strategies. Land evaluation fulfilled that issue through identification of soil limitations and producing land capability mapping units.

Soils of the area under consideration were evaluated twice. First, they were evaluated with taking into consideration the whole available parameters included in the modified Storie system. Meanwhile, the second run neglect drainage conditions and erosion hazardous effects. Results of land capability assessment for all data indicated that studied soils of Wadi Hudein are classified as "Poor" over an area of about 91.65% of the entire terrain. Non Agricultural soils are occupying an area of about 8.35 % (Table 6 and map 8A). The calculated indices specified for poor soils are ranging from 10 to 40%, while they vary from zero to 10 % for the non agricultural ones.

The hazardous effects of erosion and drainage status are influencing negatively soil ranking, so the indices were recalculated after avoiding the evaluation of drainage and erosion. Accordingly, soils of Wadi Hudein were classified into three classes. "Fair" soils were detected over 10.36 % of the total area, while "Poor" soils dominated the studied area occupying about 84.93 % of the entire terrain, and 4.71% of the Wadi Hudien delta is classified as "Non Agricultural".

Fair soils were generated as the capability indices ranged from 40 to 60 % (Table 6 and map 8B). Fair capable soils of Wadi Hudein could be considered the most suitable area for agricultural land uses with less effort required for reclamation. Poor soils reflect the existing of sever limitations regarding soil depth and salinity, where capability indices varying between 10 and 40%. Alternatives of agricultural land uses have to taken into consideration at areas of the fifth land capability category with indices from 10 to zero%. Non agricultural soils suffer from highly sever limitations regarding rock exposures, very shallow soil profile depth and/or extreme salinity. These soils are located adjacent to sea shoreline forming wet sabkha or near the mountainous area.

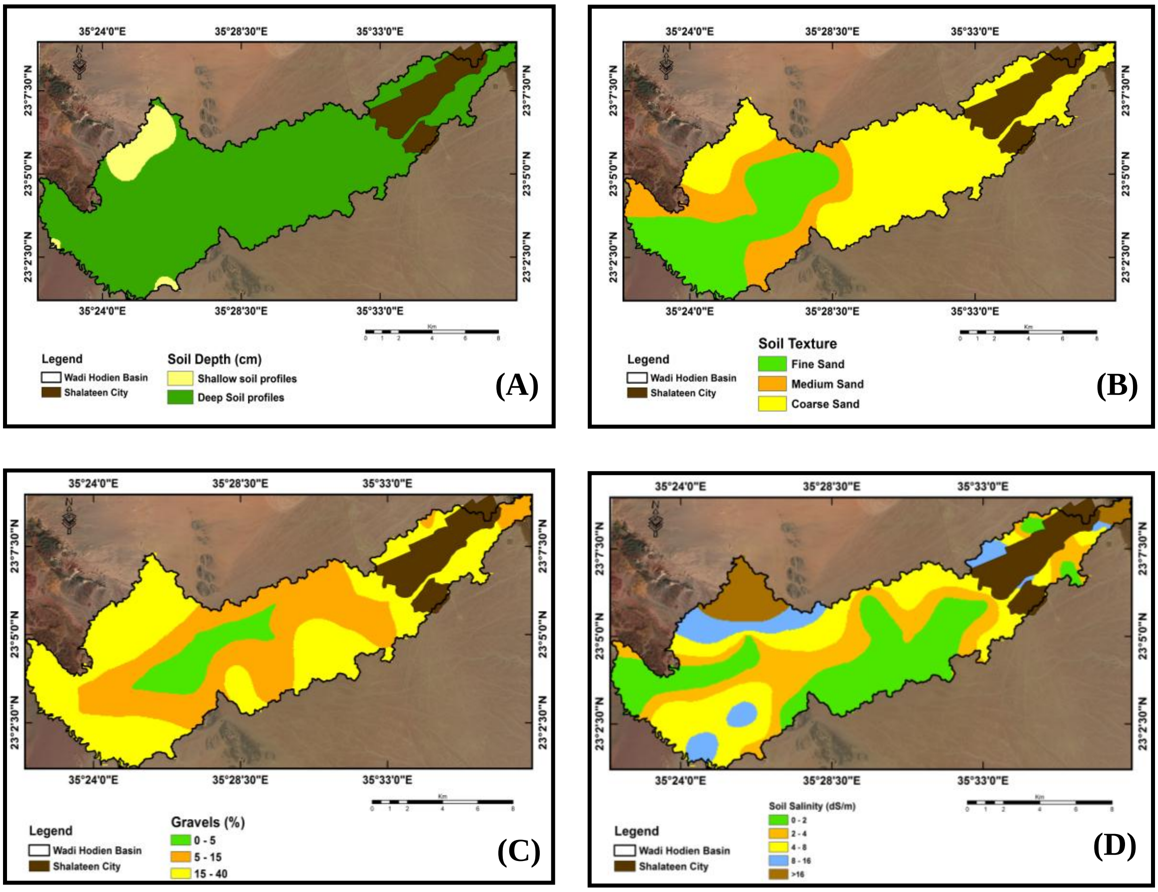
Evaluation of differentiated soil units using Storie land capability classification model revealed that delta plain of Wadi Hudien is fair to poor for sustainable agriculture as they are located within classes 3 and 4 of land capability over more than 95% of the area.

Table 4: Soil properties of the studied area at Wadi Hudien Delta.

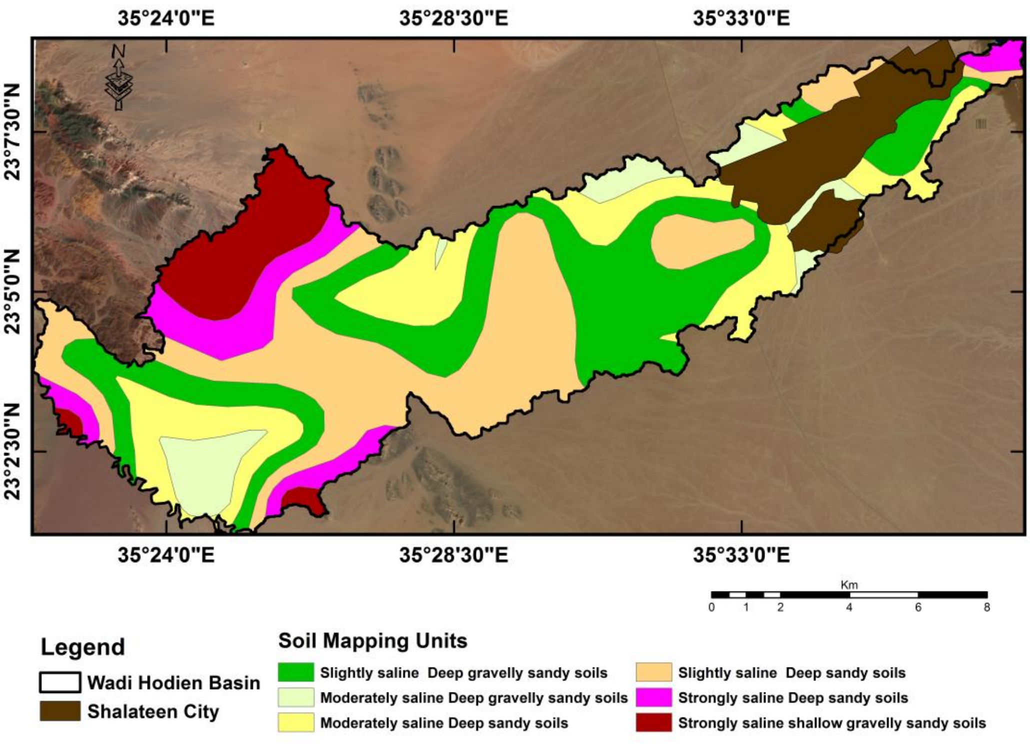
Profile No.	Depth cm	Gravel %	Particle Size Distribution % C.S	M.S	F.S	Textural class	pH	EC dS/m	$CaCO_3$ %	OM %
Landform: Sabkha										
2	0-40	0.00	61.59	27.00	11.41	Coarse sand	6.60	85.40	0.40	0.35
	40-42	0.00	56.02	41.00	2.98	Coarse sand	6.5	17.20	0.40	
	42-62	3.40	31.72	51.10	17.18	Medium and	6.80	39.40	0.40	
	62-64	0.00	15.36	9.07	75.57	Fine sand	7.40	16.47	0.0	
	64-100	6.30	20.02	5.74	74.24	Fine sand	7.30	19.35	0.40	
	100-150	11.80	26.95	14.10	58.95	Medium sand	7.60	12.62	0.99	
Landform: Wadi Channel										
1	0-40	20.60	66.10	20.39	13.51	Coarse sand	7.80	1.32	1.50	0.32
	40-90	5.60	42.91	26.00	31.09	Coarse sand	7.50	6.95	1.00	
	90-125+	11.80	34.24	27.56	38.20	Coarse sand	7.90	5.59	1.10	
23	0-15	28.60	39.05	21.50	39.45	Coarse sand	8.20	0.33	1.00	0.33
	15-30	4.00	7.59	28.53	63.88	Very fine sand	8.50	1.99	1.40	
	30-90	2.90	21.16	27.38	51.46	Fine sand	8.70	0.22	1.50	
	90-130+	8.60	35.89	32.00	32.11	Coarse sand	8.30	0.44	1.60	
28	0-45	17.10	48.88	20.99	30.13	Coarse sand	8.20	0.22	1.10	0.53
	45-90	14.70	46.77	42.15	11.08	Coarse sand	8.50	0.16	1.10	
	90-115+	35.30	60.01	21.00	18.99	Coarse sand	8.60	0.20	1.10	
Landform: Wadi Terraces										
3	0-55	12.90	28.71	25.56	45.73	Coarse sand	8.30	0.54	2.20	0.25
	0-110	12.90	28.71	25.56	45.73	Coarse sand	8.30	0.54	2.20	0.25
4	0-50	4.50	34.65	22.30	43.05	Coarse sand	7.60	0.95	1.40	0.28
	50-100	53.80	51.69	23.00	25.31	Coarse sand	7.90	0.26	2.30	
	100-130+	52.60	57.06	20.50	22.44	Coarse sand	7.90	2.47	2.61	
5	0-15	9.40	7.99	35.00	57.01	Very fine sand	8.50	1.41	1.20	0.64
	15-45	57.1	36.27	36.55	27.18	Coarse sand	8.60	4.47	1.90	
	45-80	33.3	51.02	32.57	16.41	Coarse sand	8.30	7.22	1.70	
	80-100	11.50	36.39	31.52	32.09	Coarse sand	9.40	1.00	1.70	
	100-110	52.60	48.52	34.43	17.05	Coarse sand	9.20	1.73	2.50	
	110-150	8.30	40.03	43.48	16.49	Coarse sand	9.10	1.15	1.20	
6	0-45	21.00	25.92	25.18	48.90	Coarse sand	7.70	16.79	2.40	0.48
	45-75	37.80	31.96	29.00	39.04	Coarse sand	7.60	17.68	2.00	
	75-120+	33.30	42.09	33.22	24.69	Coarse sand	7.80	4.90	0.70	
7	0-50	14.90	34.06	29.15	36.79	Coarse sand	7.90	9.07	1.70	0.38
	50-100	31.40	46.70	27.12	26.18	Coarse sand	7.70	7.87	2.40	
	100-150	27.00	62.79	26.50	10.71	Coarse sand	7.80	2.13	1.90	
8	0-40	21.20	43.17	17.00	39.83	Coarse sand	7.50	1.90	1.20	0.31
	40-80	20.00	38.90	15.00	46.10	Coarse sand	7.70	0.54	0.90	
	80-120+	3.60	48.27	32.58	19.15	Coarse sand	8.00	0.66	0.60	
9	0-40	21.20	43.17	17.00	39.83	Coarse sand	7.50	1.90	1.20	0.31
	40-80	20.00	38.90	15.00	46.10	Coarse sand	7.70	0.54	0.90	
	80-120+	3.60	48.27	32.58	19.15	Coarse sand	8.00	0.66	0.60	
10	0-30	0.00	19.56	19.00	61.44	Fine sand	7.60	10.98	1.20	0.40
	30-85	3.70	27.67	25.70	46.93	Coarse sand	7.70	4.02	2.40	
	85-120+	17.20	39.77	33.00	27.23	Coarse sand	7.70	3.92	1.90	
11	0-50	9.40	16.60	30.50	52.90	Fine sand	8.10	0.30	0.95	0.32
	50-100	2.30	15.46	30.76	53.78	Fine sand	9.00	0.22	2.00	
	100-150	5.40	42.95	35.49	21.56	Coarse sand	8.60	0.33	1.00	
13	0-30	7.40	25.00	23.00	52.00	Medium sand	7.80	9.04	2.60	0.32
	30-50	39.30	31.98	28.35	39.67	Coarse sand	7.60	6.50	2.60	
	50-110+	7.70	55.81	30.43	13.76	Coarse sand	7.90	2.72	1.70	
14	0-40	17.20	30.00	17.00	53.00	Medium sand	8.10	0.47	3.91	0.41
	40-80	26.80	30.19	17.40	52.41	Medium sand	8.30	0.42	3.60	
	80-120+	9.10	31.73	25.79	42.28	Coarse sand	8.30	0.79	1.70	
15	0-40	26.70	31.00	30.00	39.00	Coarse sand	7.70	2.91	2.30	0.40
	40-80	12.90	14.76	35.60	49.64	Medium sand	7.90	1.69	1.50	
	80-120+	46.20	52.36	26.00	21.64	Coarse sand	7.80	2.30	7.80	
16	0-50	2.90	26.00	17.71	56.29	Medium sand	8.40	2.22	1.20	0.37
	50-100	4.80	19.93	32.50	47.57	Medium sand	7.80	2.85	2.50	
	100-150	5.90	17.25	20.15	62.60	Fine sand	7.80	3.68	3.60	

Table 4: Continued

Profile No.	Depth cm	Gravel %	Particle Size Distribution %				pH	EC dS/m	$CaCO_3$ %	OM %
			C.S	M.S	F.S	Textural class				
17	0-35	0.00	2.10	16.00	81.90	Very fine sand	8.50	0.36	0.60	0.30
	35-60	20.00	32.81	45.00	22.19	Coarse sand	8.20	0.78	0.80	
	60-100	0.00	15.64	21.49	62.87	Fine sand	7.70	9.66	0.95	
	100-130+	0.00	20.98	29.26	49.76	Medium sand	7.60	7.27	1.50	
18	0-35	0.00	2.10	16.00	81.90	Very fine sand	8.50	0.36	0.60	0.30
	35-60	20.00	32.81	45.00	22.19	Coarse sand	8.20	0.78	0.80	
	60-100	0.00	15.64	21.49	62.87	Fine sand	7.70	9.66	0.95	
	100-130+	0.00	20.98	29.26	49.76	Medium sand	7.60	7.27	1.50	
21	0-20	6.70	23.27	20.50	56.23	Fine sand	8.00	4.63	1.20	0.34
	20-80	16.70	72.78	19.48	7.74	Coarse sand	8.10	1.53	1.70	
	80-120+	33.30	66.47	28.42	5.11	Coarse sand	8.10	0.75	1.90	
22	0-20	6.70	23.27	20.50	56.23	Fine sand	8.00	4.63	1.20	0.34
	20-80	16.70	72.78	19.48	7.74	Coarse sand	8.10	1.53	1.70	
	80-120+	33.30	66.47	28.42	5.11	Coarse sand	8.10	0.75	1.90	
24	0-20	21.20	42.82	26.71	30.47	Coarse sand	8.00	0.44	1.20	0.37
	20-50	3.40	5.17	9.95	84.88	Very fine sand	8.30	1.84	1.20	
	50-65	41.20	38.36	24.90	36.74	Coarse sand	8.70	1.15	2.20	
	65-120+	28.60	27.32	40.50	32.18	Coarse sand	8.50	1.17	1.10	
25	0-50	0.00	11.13	11.94	76.93	Fine sand	7.90	6.08	4.40	0.41
	50-100	0.00	7.75	20.44	71.81	Very fine sand	8.20	3.53	3.00	
	100-150	0.00	24.63	47.00	28.37	Medium sand	9.10	1.64	1.50	
26	0-50	0.00	7.36	47.50	45.14	Medium sand	8.60	1.33	0.95	0.34
	50-100	0.00	8.00	51.80	40.20	Medium sand	7.90	4.79	1.00	
	100-150	0.00	15.62	53.00	31.38	Medium sand	8.00	2.69	0.50	
29	0-40	4.00	6.46	10.52	83.02	Very fine sand	8.90	0.40	1.00	0.75
	40-60	0.00	4.00	11.26	84.74	Very fine sand	7.90	0.82	2.40	
	60-90	0.00	10.57	35.35	54.08	Fine sand	8.30	0.26	2.30	
	90-130+	20.80	68.29	21.44	10.27	Coarse sand	8.60	0.11	1.60	
30	0-20	38.50	12.44	24.00	56.56	Fine sand	7.50	18.40	4.00	0.30
	20-50	18.40	58.00	25.04	16.96	Coarse sand	7.50	7.70	2.00	
	50-85	0.00	11.04	82.37	6.59	Medium sand	7.30	12.08	1.50	
	85-110+	0.00	10.56	84.18	5.26	Medium sand	7.40	11.42	1.80	
31	0-50	12.00	22.04	32.95	45.01	Medium sand	7.80	4.22	1.90	0.81
	50-100	2.70	5.55	10.33	84.12	Very fine sand	7.50	7.74	3.90	
	100-130+	28.00	14.45	24.00	61.55	Fine sand	7.60	7.03	2.70	
34	0-10	26.70	25.46	12.00	62.54	Medium sand	8.40	0.69	0.80	0.94
	10-25	27.60	38.75	21.29	39.96	Coarse sand	7.80	3.64	2.50	
35	0-20	25.60	24.79	18.50	56.71	Medium sand	7.80	2.13	0.80	0.59
	20-35	0.00	6.70	17.75	75.55	Very fine sand	7.60	4.08	1.20	
	35-95	25.00	28.82	35.00	36.18	Coarse sand	7.30	11.77	1.50	
	95-115+	75.00	58.56	14.59	26.85	Coarse sand	7.20	17.75	1.40	
Landform: Mountain down slope										
12	0-20	35.50	39.60	33.61	26.79	Coarse sand	7.80	43.70	0.60	0.41
19	0-30	22.20	40.45	15.00	44.55	Coarse sand	8.20	0.30	1.50	0.34
	30-50	60.00	48.07	16.51	35.42	Coarse sand	8.30	0.33	0.90	
	50-90	4.80	26.00	26.00	48.00	Coarse sand	8.70	0.15	1.00	
	90-120+	0.00	8.28	36.20	55.52	Very fine sand	8.90	0.14	0.99	
20	0-20	37.50	26.00	19.00	55.00	Medium sand	7.90	11.08	2.20	0.31
27	0-30	11.40	20.06	33.50	46.44	Medium sand	8.70	0.941	1.20	0.45
	30-45	36.40	53.65	33.75	12.60	Coarse sand	8.60	0.15	0.80	
	45-70	0.00	2.71	20.85	76.44	Very fine sand	8.50	0.19	0.95	
	70-110+	6.70	18.31	46.53	35.16	Medium sand	8.60	0.27	0.95	
28	0-45	17.10	48.88	20.99	30.13	Coarse sand	8.20	0.22	1.10	0.53
	45-90	14.70	46.77	42.15	11.08	Coarse sand	8.50	0.16	1.10	
	90-115+	35.30	60.01	21.00	18.99	Coarse sand	8.60	0.20	1.10	
32	0-50	12.00	22.04	32.95	45.01	Medium sand	7.80	4.22	1.90	0.81
	50-100	2.70	5.55	10.33	84.12	Very fine sand	7.50	7.74	3.90	
	100-130+	28.00	14.45	24.00	61.55	Fine sand	7.60	7.03	2.70	
33	0-30	40.00	25.48	25.50	49.02	Coarse sand	8.80	0.17	2.70	0.54



Map 6: Averaged soil properties of (A) depth, (B) texture, (C) gravel, (D) salinity



Map 7: Soil mapping units of the studied area at Wadi Hudien Delta.

Table 5: Soil mapping units of the studied area at Wadi Hudien Delta.

Soil Unit	Description	Soil Taxa	Area Feddan, (%)
SMU01	Moderately saline deep gravelly sandy soils	*Typic Torripsamments*	3366 (10 %)
SMU02	Moderately saline deep sandy soils	*Typic Torripsamments*	6211 (18 %)
SMU03	Slightly saline deep gravelly sandy soils	*Typic Torripsamments*	9712 (29 %)
SMU04	Slightly saline deep sandy soils	*Typic Torripsamments*	9592 (28 %)
SMU05	Strongly saline deep sandy soils	*Typic Haplosalids*	2467 (7 %)
SMU06	Strongly saline shallow gravelly sandy soils	*Miscellaneous soils*	2736 (10 %)

Table 6: Land capability of soil units at Wadi Hudien delta.

Soil Mapping Units	Storie index (1) %	Capability class (1)	Storie index (2) %	Capability class (2)
SMU01	15.72	Poor	23.11	Poor
SMU02	21.72	Poor	31.94	Poor
SMU03	23.84	Poor	35.05	Poor
SMU04	27.63	Poor	40.63	Fair
SMU05	4.72	Non-agricultural	6.94	Non-agricultural
SMU06	4.14	Non-agricultural	6.08	Non-agricultural

(1) Capability index and class including assessment of erosion and drainage
(2) Capability index and class excluding assessment of erosion and drainage

Table 7: Land suitability of some selected crops at soil units of Wadi Hudien delta.

Soil Mapping Units	Citrus	Alfalfa	Sunflower	Barley	Wheat	Sorghum	Maize	Olives
SMU01	S3	S3	S2	S1	S3	S1	S3	S2
	51.97	57.41	68.67	96.37	56.34	94.23	47.45	70.34
SMU02	S3	S2	S2	S1	S3	S1	S3	S2
	52.91	61.49	73.13	100.00	58.16	100.00	58.90	70.34
SMU03	S3	S3	S2	S1	S2	S1	S3	S2
	52.77	58.28	69.65	91.62	73.56	95.89	57.72	65.60
SMU04	S3	S3	S2	S1	S2	S1	S3	S2
	53.65	59.15	70.88	93.44	74.45	97.24	58.57	65.43

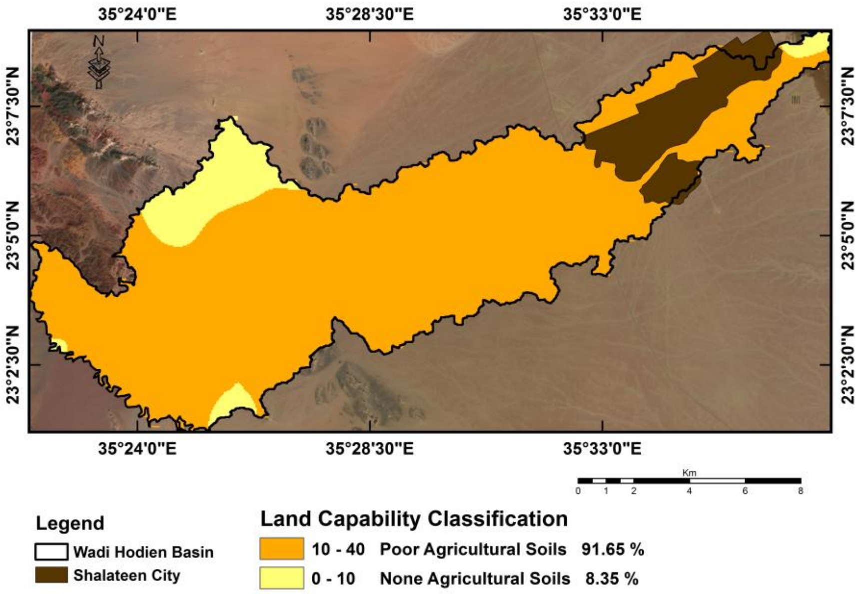
Soils of wadi course, delta and alluvial plains were suitable for agricultural production under proper management of salt affected soils and flash floods. The main limitations for development in this area were the severe climatic conditions, extreme salinity and erosion hazard.

Land suitability investigation revealed that soils of Wadi Hudien were found to be suitable for producing barely, sorghum, wheat, olives, alfalfa, maize, sunflower and citrus (Table 7).

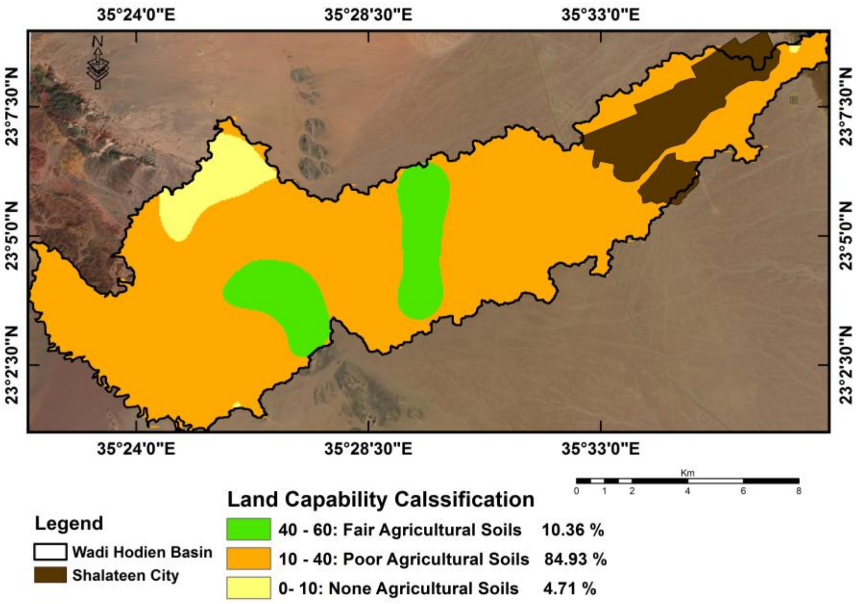
Land suitability of Alfalfa is classified as suitable (S2) over 19.94% of the total area and as moderately suitable (S3) over 80.06% of the area (Table 7 and Map 9-A). Meanwhile, studied soils are highly suitable (S1) for Barely over 70.72% of the total terrain (Table 7 and Map 9-B). Regarding fruits suitability the area found to be suitable (S2) and moderately suitable (S3) for Olives over 58.44% and 23.65%, respectively (Table 7 and Map 9-C). In general, Barely and Sorghum were assessed as the most optimum crops in the studied soils. They got 100% as evaluation index (100% aptness) at soil unit SMU02, whereas their indices ranged between 91.6 and 97.2% at soil units SMU01, SMU03 and SMU04.

In addition to achieved land suitability for producing different crops, attention must be paid to protect valuable fauna and flora, and marine natural resources. Current investigation emphasized that soils of Wadi Hudien delta as an alluvial plain were suitable for agricultural production under proper management of flash floods, which represent the main type of water resources in this region.

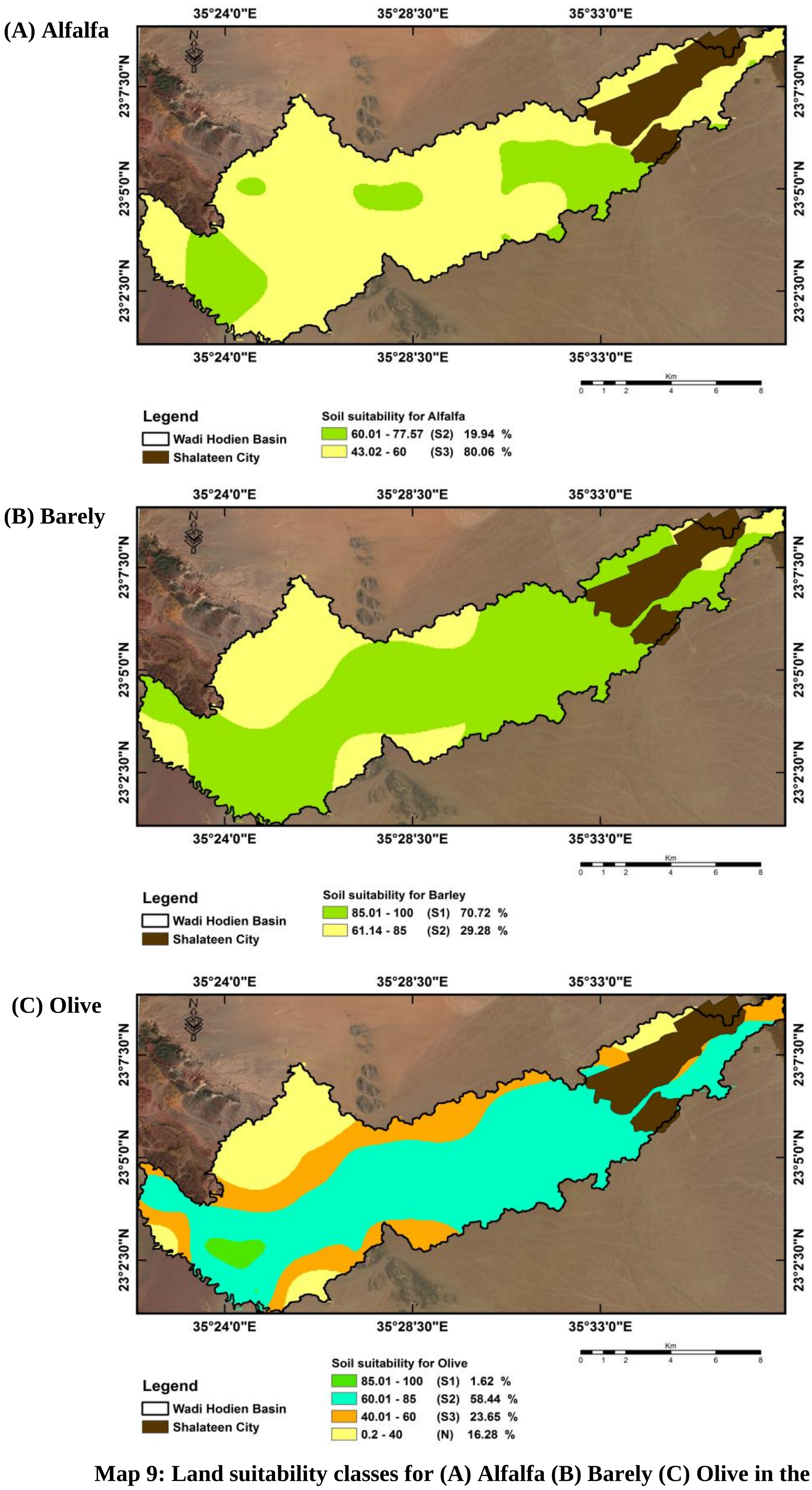
(A)



(B)



Map 8: Land capability classes of the studied area:
(Erosion and drainage (A) were considered (B) not considered)



Map 9: Land suitability classes for (A) Alfalfa (B) Barely (C) Olive in the studied area at Wadi Hudien

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الملخص العربى

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تعد أراضى مثلث حلايب والشلاتين بالجنوب الشرقى لمصر من النوعيات الواعدة للإستغلال الزراعى، ولتعظيم درجة الإنتفاع الأرضى منها لابد من تخطيط إدارتها الزراعية على نحو سليم. ويهدف البحث إلى تحديد معوقات الإستغلال الأرضى والتى تؤثر سلبيا على الانتاجية الزراعية بوادى حوضين كأحد أهم أحواض التجميع المائى بالمنطقة، وذلك بهدف الوصول الى أفضل إنتاجية زراعية تحقيقا للتنمية الزراعية المستدامة بالمنطقة. أختيرت منطقة الدراسة لتمثل دلتا حوض التجميع المائى لوادى حوضين بمنطقة الشلاتين والتى تمتد على مساحة ١٤٣ كم٢ (حوالى ٣٤ الف فدان). أظهرت نتائج التحليل بإستخدام نظم المعلومات الجغرافية لخرائط الميل والنموذج الرقمى للإرتفاعات أن دلتا وادى حوضين بدت كسهل شاسع منبسط هين الميول حيث تم أشتملت من الشرق للغرب على الأشكال الأرضية السبخات الساحلية – المصاطب النهرية– الميول الجبلية الدنيا إضافة لمجرى الوادى نفسه.

تم حصر تربة المنطقة بالإستعانة بمعالجة مرئية لاندسات ٨ الفضائية الممثلة لكافة الأشكال الأرضية بها، حيث تم حفر عدد ٣٧ قطاع أرضى مع تجميع عينات التربة الممثلة لها لتقدير صفاتها المختلفة معمليا. ولقد تم تقسيم منطقة الدراسة لعدد(٦) وحدات أرضية تباينت فيما بينها فى صفات عمق قطاع التربة– قوام التربة– نسبة الحصى – نسبة الملوحة، حيث سادت وحدة الأراضى العميقة الحصوية الرملية هينة الملوحة أراضى المنطقة تلاها وحدة الأراضى العميقة الرملية هينة الملوحة على ٢٩و ٢٨% بالترتيب من إجمالى المساحة المدروسة، واللتان تم تصنيفهما ضمن أراضى تحت المجموعة الكبرى *Typic Torripsamments* تبعا للتقسيم الأمريكى الحديث. تم تقييم التربة بإستخدام دليل ستورى المعدل(٢٠٠٨)، حيث أوضحت النتائج أن قدرة التربة الإنتاجية لدلتا وادى حوضين تتبع الأراضى الفقيرة على مساحة ٩١.٦٥% من إجمالى المساحة، بينما صنفت كأراضى غير زراعية على المساحة المتبقية.

ونظرا لتدنى مستوى تقييم التربة وفقا للتأثيرات السلبية لكل من التعرية المائية والصرف والقابلان للتحسين تبعا للإدارة الزراعية السليمة تم إعادة التقييم بعد إستبعادهما حيث صنفت التربة تبعا لقدرتها الإنتاجية إلى ثلاث أقسام هى أراضى متوسطة القدرة وفقيرة وغير زراعية على إمتداد مساحات ١٠.٣٦ و ٨٤.٩٣ و ٤.٧١% على الترتيب من إجمالى مساحة دلتا وادى حوضين، وعليه فإن أكثر من ٩٥% من المساحة تعد صالحة للتنمية الزراعية المتواصلة إذا ما توافرت سبل الإدارة الزراعية المناسبة للحيلولة دون أخطار التعرية المائية وتأثيرات التربة الملحية على المحاصيل النامية. وإنحصرت محدات الإستغلال الزراعى ببعض المساحات والتى حددتها الدراسة فى وجود التكشفات الصخرية وضحالة عمق التربة والملوحة الشديدة فضلا عن عموم قسوة الظروف المناخية السائدة. كما أوضحت النتائج صلاحية التربة لإستزراع عدد من المحاصيل فى مقدمتها الشعير والسورجم والقمح والزيتون والبرسيم والذرة ودوار الشمس والموالح.

حيث تم تصنيف محصولى الشعير والسورجم كأفضل محاصيل ملائمة للإستزراع حيث بلغ دليل الملائمة ١٠٠% بوحدة التربة SMU02 بينما تراوح دليل الملائمة للمحصولين بين ٩١.٦ و٩٧.٢% بوحدات التربة SMU01 و SMU03

و SMU04. وأوصت الدراسة بضرورة الإهتمام بنشر زراعة النباتات الطبية والعطرية إستغلالا للإنعزال البيئى بالمنطقة، إضافة لإستغلالها فى زراعة النباتات الصحراوية المتحملة للملوحة كعلف للحيوانات. مع إعتبار دلتا وادى حوضين صالحة فى العموم للإستغلال الزراعى، شريطة تطبيق الإحتياطات اللازمة والضرورية لدرء مخاطر السيول.