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Assessment of land sensitivity to desertification for Al Mussaib project using MEDALUS approach

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ABSTRACT

This study was conducted to assess the sensitivity of the land of Al Mussaib project for desertification within the Babylon governorate in Mid Mesopotamian plain. A 35 surface soil sample sites were identified and were distributed over the 12 largest areas of soil series and various soil types covered the area. Standard and adjusted Mediterranean desertification and land use (MEDALUS) approaches were applied, and the environmental sensitivity area indices (ESAI) for 2021 were calculated to obtain desertification-sensitive land types. New parameters were added to the soil quality indicator (SQI) while irrigation water quality indicator (IWQI) was considered as a new one. The results indicated that the area of low soil quality was 31.83%, while that of moderate quality was 68.16%, and the vegetation quality indicator (VQI) was of the low class for the whole region. IWQI indicated that the area of moderate quality was 74.38%, while the low quality was 25. 61%. The values of ESAI ranged from 1.356 to 1.541 indicating that ESAs to desertification were in two types according to adjusted MEDALUS approaches, critical at 94.47 % and fragile at 5.52 %, was arranged as subtypes (C2-C1-F3-C3) with a percentage of 64.58, 28.23, 5.52, and 1.66% respectively. On the other hand, the critical class was prevalent in all the regions according to the standard MEDALUS approaches, with two subtypes including C1 at 6.30% and C2 at 93.69%. Pearson's Correlation showed a significant positive correlation to ESAI values with the indices used in its evaluation, the highest was with IWQI, SQI and VQI by 0.901, 0.861 and 0.852 respectively.

Keywords: ESAI, MEDALUS, Sensitivity to Desertification. Soil Quality Indicator.
Article type: Research Article.

INTRODUCTION

Desertification is a complex phenomenon that leads to a decrease in land productivity, which results from biophysical interaction and human factors with temporal and spatial changes. Adamo & Crews-Meyer (2006) defined desertification as land degradation in arid, semi-arid, and semi-wet areas, which collectively are called dry lands. Their study in the Jachal region in San Juan Province showed that drought is not the only process that has led to a decrease in soil quality and a decrease in vegetation, but there are natural resource management issues, especially water and natural vegetation, as well as permanent population settlement, which has led all to environmental problems such as soil salinization and deforestation. Further, they concluded that land degradation must be included among the environmental risks even if the outbreak of desertification is not yet clear. Basso *et al.* (2000) stated that the environmental degradation or sensitivity of an area is a broad concept, and environmentally sensitive area (ESA) can be considered, in general, a specific entity where the environmental, social, and economic factors are unbalanced or unsustainable for that particular environment. Kosmas *et al.* (1999) used the Mediterranean desertification and land use (MEDALUS) approach to focus on environmental sensitivity areas (ESAs) to desertification through a multi-factor approach to defining environmental sensitivity area index (ESAI) based on soil quality, climate, vegetation, and management. This approach is simple, robust, broad-based, applicable, and adaptive to new information. A study by Guo *et al.* (2017) in Ordos Plateau, in the arid and semi-

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arid regions of northern China, showed that different scenarios are needed according to local conditions to reduce desertification locally to achieve sustainable development. Besides, human activities can help reduce desertification locally, such as afforestation to improve the environment locally. Moreover, Rasmy *et al.* (2010) described a dynamic simulation model of desertification, to be able to predict the sensitivity to desertification in Western Nile Delta, Egypt, using the MEDALUS model which was developed by the European Commission in 1999. They found that an increase in population leads to an elevation in urbanization and this leads to a decrease in arable lands and thus a decrease in vegetation and desertification, by adopting several indices (soil quality, climate quality, vegetation quality, management quality), to obtain ESAs and to access the desertification sensitivity index (DSI) or ESAIs. Sepehr *et al*. (2007) used adjusted MEDALUS approach by six main indices or factors (soil, climate, erosion, plant cover, groundwater, and management) for the quantitative evaluation of the desertification process in the southern Iranian plain. For each of them, sub-indices were identified, where each of them was evaluated according to its quality. A certain weight was given and then the geometric average of the six indicators was found to give the state of desertification on the map. Symeonakis *et al*. (2014) assessed sensitivity to land degradation and desertification using ESAI on Lesvos Island in Greece and used 21 quantitative parameters divided into five indices (climate, vegetation, soil, groundwater, socio-economic). Their results showed that 85% of the island is fragile or critically sensitive. Salvati & Bajocco (2011) pointed out, through their calculation of the ESAI value, that there has been an increase in the surface area of sensitive regions of degradation during the last fifty years in southern Italy. Thus, the lack of rain, increasing population density, and agricultural intensification have led to a high level of sensitivity in the north as well. Similarly, Salvati *et al*. (2011) found that critical lands in Italy are those located along the coastal lowlands where population and economic activities are concentrated in general. In addition, they found that some lands with unfavorable climatic conditions and geo-morphological features, have led to the formation of canyons and weak land cover associated with unsustainable exploitation of the agriculture land. The study of Aziz & Al-Ali (2014) on the land sensitivity of desertification in Kuwait, was based on three main spatial standards: characteristics of soil in type, geomorphologic characteristics, and finally biological characteristics. They recommended applying other standards like climate characteristics and human activities, as factors that may have a role in the increase of land sensitivity to desertification. In Lebanon, Kamel *et al*. (2015) applied the MEDALUS approach in an arid region by adding specific parameters such as rock hardness, permeability, soil organic matter, clogging, and erodibility as well as excluding others (soil depth, texture parent material). Contador *et al.* (2009) stated that the MEDALUS approach has been widely used as a successful tool to discover the most vulnerable and degraded areas and is highly resilient and allows for adaptation based on local conditions and available information. Bakr *et al*. (2012) used the adjusted MEDALUS approach, where the SQI equation was adjusted including soil texture, parent material, rock fragment, slope, soil depth, drainage, SOM, EC, and pH, then a new equation for irrigation water quality indicator (IWQI) was used. Karamesouti *et al*. (2018) were also used MEDALUS to assess the sensitivity and risks of desertification in Greece using the basic indicators recommended by the original MEDALUS report. Therefore, this study aims to assess the environmentally sensitive areas of desertification (ESAs) in the Al Mussaib project area through: (1) Evaluating the most important parameters and indicators of the environmental sensitivity of desertification for the lands of the study area; (2) Developing an adjusted and proposed model for MEDALUS to obtain more reliable data at the local level; (3) Calculation of ESAI and identification of types and subtypes of ESA_S and their spatial distribution in the study area.

MATERIALS AND METHODS

Location of the study area

Al Mussaib project is located in Babylon Governorate within the lands of the central Iraqi sedimentary plain about 80 km east of the Euphrates, between the Tigris and Euphrates rivers. It is a part of the waterborne sediments due to the momentum of the carrier factor and here is the water of Euphrates River and its branches. A satellite image for the study area in 2021 was obtained from the Land sat 8 satellite; the image was taken in 12/2/2021; the percentage of cloud cover was 0 %; and its coordinates was between 32° 48′ - 32° 32′ N and 44° 55′ - 44° 29′ E. The area of the Al Mussaib project is estimated as 5836.95 km^2. Most of its lands are used for agricultural purposes, and there are lands for public utilities, including roads, villages, and hills, at a ratio of 0.23% of the total area only. Furthermost of its lands are irrigated from a channel branching from the Euphrates River called the Al Mussaib project channel, which its length is about 9.6 km. Its physiographic units vary between depression and low basins and also irrigation and river levees interspersed with some dunes and hills dating back to ancient times (Ajam 2010). Its lands were irrigated in surface irrigation method, however, after the low level of the Euphrates River and its streams, pumps were used to raise water from the water channels. Groundwater was used to irrigate some areas due to the lack of water shares, which was reflected in the spread of saline areas in some of the study areas. There are some open and lined drains spread in the project lands, since the project lands are nearly level, with a slope of 0.8%, and its soil is sedimentary. Its soil has been classified into Typic Torrifluvents (Soil Survey Staff 2010), in which some natural plants such as *Alhagi maurorum, Typha angustata* are spread. These lands are exploited by cultivating many summer and winter crops, including vegetable and grain crops such as wheat, barley, maize, beans, and fodder crops, as well as orchards and using irrigation agriculture system. Fig. 1 shows the location of the study area.

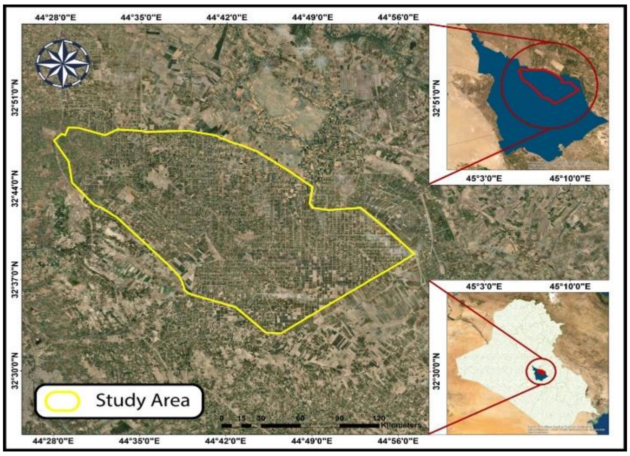


Fig. 1. The location of the study area.

The climate of the study area

Climate is the main factor in the occurrence of drought phenomenon that prevails in arid and semi-arid regions, including the study area, characterized by high daily and annual temperature variation, lack of vegetation, and high evaporation/transpiration rate. The climatic data from the Babylon metrology station for the years 1997-2020 were adopted, where the highest average temperature was 36.3 °C in July, while the lowest was 12.9 °C in January and the annual average was 25.8 °C. Likewise, the average rainfall was 114.3 mm, while the relative humidity increased in the winter months, then decreased in the hot summer months, reaching an annual average of 39.5%. It is inversely proportional to the temperature changes that are reflected in the values of evaporation (2529 mm). The thermal system of soil is of the hyperthermic regime, and the soil moisture regime is Ardic (torric). These climatic conditions greatly affect the decomposition and oxidation of organic matter, salinity, and different soil characteristics (Table 1).

Table 1. The monthly and annual average of some climate elements in the Babylon weather stations (1997-2020).

Climate elements	Months												Annual mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec	
Max Tem.	17.3	22.2	25.3	32.0	35.1	43.1	46.4	45.3	42.1	35.4	26.1	19.8	32.5
Min Tem. (°C)	5.2	7.3	12.2	18.2	23.5	25.2	29.1	30.1	24.2	19.1	11.2	7.3	17.71
Mean (°C)	12.9	14.6	22.9	25.3	29.5	35.3	36.4	36.1	33.4	29.5	19.9	13.8	25.8
Rain fall (mm)	18.7	17.3	22.6	16.4	9.3	0.0	0.0	0.0	0.3	3.5	11.5	14.7	114.3
Humid Relative (%)	64	58	52	40	33	23	22	18	24	35	44	61	39.5
Evaporation (mm)	33	58	93	130	290	370	410	390	340	250	120	45	2529
Evapotranspiration	93.07	118.55	198.23	273.24	358.21	503.96	529.30	551.02	466.56	347.51	203.21	105.68	312.38

Sampling

The soil of the study area was examined in a semi-detailed survey by Al-Moussawi (1997), in which 18 soil series were found, categorized according to AI-Agidi (1976) to classify the Iraqi sedimentary soils. Using ArcMap 10.3, the soil types were determined in the study area (Abdul-Ameer *et al.* 2019). As the soil series were multi-types, the soil type was determined according to the surface horizon soil texture for each series. Only the largest area of 12 soil series were selected, with varying areas and frequencies. A number of 35 soil sample sites were identified and were distributed into 12 soil types to cover the project area and were compatible with the area of each series. For example, the largest area of soil series was the MM11 series, and the most frequent by 29 reiterations, 5 samples were selected from them. Whereas, the DF95 series was with one reiteration and two samples were identified in this series, and so on. The rest of the other soil series as shown in Fig. 2. Using Arc GIS 10.8, the normalized difference vegetation index (NDVI) was calculated for each surface soil sample as:

NDVI = (NIR-RED) / (NIR + RED) (Rouse *et al*. 1973). The spatial distribution maps of indices used in MEDALUS approaches were also mapped using the inverse distance weighting (IDW) method. Table 2 showed the soil series, types, and soil samples selected. An exploratory survey was conducted to determine the difficulties faced in determining the sample locations and the ability to access them easily. Moreover, using the GPS of WGS 1984, the sample locations were determined, then the upper horizon texture that determined the type of soil series morphologically and laboratory was verified. The internal drainage type was verified by determining the depth of mottling in the soil column, and also by determining the soil depth. The surface soil samples 0-30 cm were then collected and passed through a 2 mm sieve and preserved to conduct physical and chemical analyzes, namely: texture, organic matter (OM) rate (%), electrical conductivity (EC as ds/m), PH, $CaCO_3$ rate (%) of soil. The characteristics of ECw, chloride (Cl), sodium adsorption ratio (SAR) were also measured in samples of irrigation water used in the study area. These characteristics are measured because they are parameters to be included in the calculation and evaluation of indices used in the adjusted MEDALUS approach.

Table 2. Soil series and types, area (%), frequency, samples and NDVI values in the study area.

Soil series	Area (%)	Frequency	Soil types	Selected samples	X	Y	NDVI
MM11	21.76	29	MM11-SiCL	1	44.61149207	32.66014764	0.134456
				2	44.81113001	32.66514978	0.072451
				3	44.73795623	32.75705987	0.084633
				4	44.56221332	32.79938863	0.538542
				5	44.50084496	32.74442091	0.143963
DM97	11.88	15	DM97-SiL	6	44.56637055	32.69654754	0.537772
				7	44.68898478	32.71765943	0.259759
				8	44.70495752	32.78303157	0.535599
DW95	10.71	12	DW95-L	9	44.57918588	32.74691561	0.537660
				10	44.79838087	32.60354738	0.181087
				11	44.61963442	32.69363025	0.539275
DM56	9.97	17	DM56-SCL	12	44.69278988	32.67396561	0.297782
				13	44.50585624	32.78284583	0.553080
				14	44.76849428	32.66529913	0.3٥٣٥١٩
MW5	7.85	10	MW5-SiCL	15	44.60692133	32.73552818	0.٥٣٣٥١٩
				16	44.78931406	32.68917406	0.٣٨٨٠٤١
				17	44.53369027	32.75646626	0.538375
DF97	7.22	9	DF97-CL	18	44.78896353	32.57392336	0.050644
				19	44.9387732	32.64177064	-0.005653
				20	44.83896259	32.6846759	0.063384
MM9	6.98	9	MM9-SiCL	21	44.84833889	32.62672244	-0.008871
				22	44.65489257	32.6118255	0.048766
				23	44.74766828	32.70892705	0.138692
DW44	6.27	12	DW44-CL	24	44.76907746	32.64146187	0.٣٨٨٦٩٢
				25	44.59935821	32.7915671	0.546150
				26	44.70751923	32.63868485	0.375478
DM55	5.80	7	DM55-L	27	44.6345435	32.75017934	0.536678
				28	44.71041189	32.7124134	0.٣٢٢٩٠٩
DW45	4.14	7	DW45-CL	29	44.65819727	32.71184051	0.537555
				30	44.7381872	32.67804158	0.060278
				31	44.78581148	32.62559925	0.389997
DM115	1.65	6	DM115-SiCL	32	44.65340052	32.66265233	0.142601
				33	44.66115322	32.7586415	0.148592
DF95	1.40	1	DF95-SiCL	34	44.88156494	32.61814895	0.19763
				35	44.90735083	32.63414535	0.193801

Quality indicators	class	parameter	score	description
SQI		(Texture)		
	1	L,SCL,SL,LS,CL	1	Good
	2	SC,SiL,SiCL	1.2	Moderate
	3	Si,C,SiC	1.6	Poor
	4	S	2	V. Poor
		(Parent material)		
	1	Shale,Schist,basic,Ultrabasic, Conglomerates ,unconsolidated	1	Good
	2	Limestone, marble, granite, Rhyolite, Ignibrite, gneiss, siltstone, sandstone	1.7	Moderate
	3	Marl, Pyroclastics	2	Poor
		(Rock fragment %)		
	1	>60	1	V. Stony
	2	20 - 60	1.3	Stony
	3	< 20	2	Bare to slightly stony
		(Slope gradient)%		
	1	<6	1	V. Gentle to flat
	2	6 -18	1.2	Gentle
	3	18-35	1.5	Steep
	4	>35	2	V. Steep
		Soil depth (cm)		
	1	>75	1	Deep
	2	30-75	1.2	Moderate
	3	15-30	1.5	Shallow
	4	<15	2	V. Shallow
		(Drainage status)(a)		
	1	---------------	1	Well drained
	2	---------------	1.2	Imperfectly drained
	3	----------------	2.0	Poorly drained
CQI		Rain fall (mm)		
	1	>650	1	----------------
	2	280-650	1.5	---------------
	3	<280	2	-----------------
		(Aridity BGI) (b)		
	1	<50	1	
	2	50-75	1.1	
	3	75-100	1.2	
	4	100-125	1.4	
	5	125-150	1.8	
	6	>150	2	
VQI		(Fire risk)		
	1	bare land, perennial agricultural crops, annual agricultural crops (maize, tobacco, sunflower)	1	Low
	2	annual agricultural crops (cereals, grasslands), deciduous oak, (mixed), mixed Mediterranean, macchia/evergreen forests	1.3	Moderate
	3	Mediterranean macchia	1.6	High
	4	pine forests	2	V. High
		(Erosion protection)		
	1	Mixed Mediterranean macchia/evergreen forests	1	V.High
	2	Mediterranean macchia, pine forests, Permanent grasslands, evergreen perennial crops	1.3	High
	3	Deciduous forests	1.6	Moderate
	4	Deciduous perennial agricultural crops (almonds, orchards)	1.8	Low
	5	Annual agricultural crops(cereals), annual grasslands, vines, (bare land) (c)	2	V.Low
		(Drought resistance)		
	1	Mixed Mediterranean macchia/evergreen forests, Mediterranean macchia	1	V.High
	2	Conifers, deciduous, olives	1.2	High
	3	Perennial agricultural trees (vines, almonds, orchard)	1.4	Moderate
	4	Perennial grasslands	1.7	Low
	5	Annual agricultural crops, annual grasslands, (bare land) (c)	2	V.Low
		(Plant cover) or vegetation cover VC%		
	1	>40	1	High
	2	10-40	1.8	Low

MQI		Land use intensity (cropland)		
	1	Low land use intensity (LLUI)	1	
	2	Medium land use intensity (MLUI)	1.5	
	3	High land use intensity (HLUI)	2	
		(Policy)		
	1	Complete: >75% of the area under protection	1	High
	2	Partial: 25-75% of the area under protection	1.5	Moderate
	3	Incomplete: <25% of the area under protection	2	Low

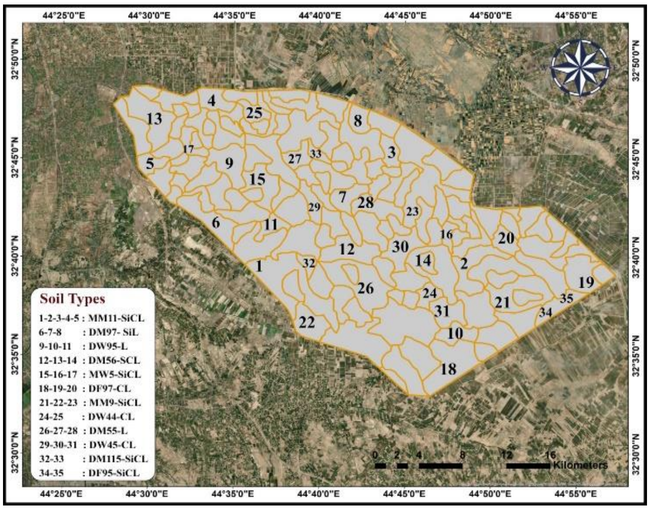


Fig. 2. Soil types and samples in the study area.

Environmental indicators of standard MEDALUS approach

The standard MEDALUS approach includes many quality indexes developed by the European Commission (Kosmas *et al.* 1999; Table 3) The indicators and the parameters that will be applied in the current research are as follows:

1. SQI = soil quality indicator
   SQI = (texture × parent material × rock fragment × depth × slope × drainage) $^{1/6}$
2. CQI = climate quality indicator
   CQI = (rainfall × aridity)$^{1/2}$
3. VQI = vegetation quality indictor
   VQI = (fire risk × erosion protection × drought resistance × vegetation cover) $^{1/4}$
4. MQI = management quality indicator and human factors

The standard of agricultural land-cropland was used, considering that the study area is used agricultural and not pasture land or natural areas or mining areas or reaction areas. Hence the classification of policies related to environmental protection as:

MQI = (land use intensity × policy enforcement)$^{1/2}$

Table 3. Quality indicators, parameters, score, the description used for application of the standard MEDELUS in the study area.

(a) (Drainage status) = (Other scores are suggested for this standard in Table 4)

(b) (Aridity BGI) = Simple Bagnouls-Gaussen aridity index (Another measurement has been suggested in Table 4)

(c) (bare land) = According to Bakr *et al*. (2012).

Adjusted MEDALUS approach

The MEDALUS approach is highly flexible and allows it to be updated based on the available local conditions and data. Therefore, some parameters have been added to the standard MEDALUS approach due to our need for them in line with the characteristics of the Iraqi sedimentary plain and the prevailing climate conditions.

1- In addition to soil texture, parent material, slope gradient (%), soil depth, drainage, rock fragment (DIS4ME 2004) measurements and scores for some other parameters have been suggested, as some soil characteristics have been added to SQI, such as OM (%), EC (ds m^{-1}), PH, $CaCO_3$ (%), as the Iraqi sedimentary soils are characterized as highly calcareous soils with a percentage of calcium carbonate between 20% and 30% (Buringh 1960). The report of FAO (1973) indicated that soils in areas affected by the Mediterranean and desert climates contain carbonate minerals that are inherited from the parent material. The prevalent soils in arid and semi-arid regions are calcareous soils due to climatic factors and the long dry season.

The carbonate content of soils affects the stability of soil and changes in the values of soil susceptibility to erosion factor due to its effect on the values soil particle size distribution (Hassan 2012). In addition to its organic matter content, which although it is low, however, has an important and influential role in soil characteristics (Chaney & Swift 2005). Furthermore, soil PH and soil salinity values characterize the Iraqi soils because of their impact on the characteristics of other soils and their degradation. Scores of some parameters were adjusted, including the class of drainage, which was divided into five classes. In addition, other parameters were divided according to the requirements of Iraqi soils, which are characterized by low organic matter, high salinity values and high pH due to the presence of $CaCO_3$. This index can be calculated as follows:

$$\mathrm{SQI} = (\mathrm{texture} \times \mathrm{parent\ material} \times \mathrm{rock\ fragment} \times \mathrm{slope\ gradient\%} \times \mathrm{soil\ depth\ (cm)} \times \mathrm{drainage} \times \mathrm{OM\%} \times EC\ ds/m \times \mathrm{PH} \times \mathrm{CaCO_3\%})^{1/10}$$

1. To compute aridity in CQI, the potential evapotranspiration (PET) was calculated according to the IVANOV equation mentioned by Al-Rawi & Al-Samurai (1990), and then the value of aridity was calculated by dividing the rain rate P by PET9 (UNEP 1991; Bakr 2012):

$$\mathrm{PET} = 0.0018\ (25 + \mathrm{T})^2 (100 - A)$$

$$\mathrm{CQI} = (\mathrm{Rainfall\ (mm)} \times \mathrm{Aridity}\ {}^{P}/_{PET})^{1/2}$$

2. In the VQI index, a plant cover or percentage of vegetation cover [VC (%)] was calculated according to the equation given in EI Hassan (2004) which was developed by Porevdorj (1998):

$$\mathrm{VC\%} = -\,4.337 - 3.733 \times \mathrm{NDVI} + 161.968 \times \mathrm{NDVI}^2$$

$$\mathrm{VQI} = (\mathrm{Fire\ risk} \times \mathrm{Erosion\ protection} \times \mathrm{Drought\ resistanc\ X\ \ VC\%\ or\ plant\ cover})^{1/4}$$

3. The irrigation water quality ndex (IWQI) and its standards including ECw, Cl and SAR were added, and the range values were chosen according to what was included in the irrigation water quality guide lines (Ayers & Westcot 1985). Given that the project lands are part of the alluvial plain lands that are subject to the irrigation agriculture system, the quality of irrigation water will have an effect on the soil characteristics and the productivity of land (Table 4).

Environmental sensitivity area index (ESAI)

The value of previously-mentioned indices is estimated as the geometric mean of the weighted average for each single parameter within this index or indicator, and that each parameter in each quality index has a score ranged between 1, representing best condition (for the least desertification-sensitive areas) to 2, representing worst condition (for the most desertification-sensitive areas). For the standard MEDALUS approach, the ESAI was calculated by:

$$\mathrm{ESAI} = (SQI \times \mathrm{CQI} \times \mathrm{VQI} \times \mathrm{MQI})^{1/4}$$

The ESAI is an adjusted MEDALUS approach was calculated:

$$\mathrm{ESAI} = (\mathrm{SQI} \times \mathrm{CQI} \times \mathrm{VQI} \times \mathrm{MQI} \times \mathrm{IWQI})^{1/5}$$

Table 5 shows the ranges and classes of indicators.

Environmental sensitivity areas to desertification (ESAs)

Depending on the ranges of ESAI, there are three types or classes of ESAS, namely Critical, Fragile, and Potential, each has a subtype ranged between 3 (the highest sensitivity) and 1 (the least sensitive), and each has a specific range (Table 6).

Table 4. Adjusted quality indicators, parameters (values and scores).

Quality indicator	class	parameter	Score	description	
			drainage		(soil survey manual 2017)
	1	Mottling at >150 cm	1	Excessively drained	
	2	90-150	1.2	Well drained	
	3	50-90	1.4	Moderately well drained	
	4	25-50	1.6	Imperfectly drained or (somewhat poorly drained)	
	5	Less than 25	1.8	Poorly drained	
	6	Frequently ponded	2	v.poorly drained	
			OM %		Lab analysis, (Al-Agidi 19٩٠)
	1	>2.5	1	High	
	2	1.5-2.5	1.5	Moderate	
	3	<1.5	2	low	
			EC(ds/m)		Lab analysis, (Soil survey manual 2017)
SQI	1	<2	1	Non saline	
	2	2-4	1.2	Very slightly saline	
	3	4-8	1.5	Slightly saline	
	4	8-16	1.8	Moderately saline	
	5	>16	2	Strongly saline	
			PH		Lab analysis, (Soil survey manual 1951)
	1	<5.5	2	v.low	
	2	5.5-6.5	1	Low	
	3	6.5-7.5	1.5	Moderate	
	4	7.5-8.4	1.7	High	
	5	>8.4	2	v.high	
			$CaCO_3$ %		Lab analysis (Al-Agidi 1986)
	1	<3	1	Slightl careously	
	2	3- 15	1.7	Moderately =	
	3	>15	2	Strongly =	
			Aridity P/PET		(UNEP 1991 ;Baker,*etal* .2012)
CQI	1	>0.65	1	Humid	
	2	0.50-0.65	1.2	Sub humid	
	3	0.20-0.50	1.5	Semi arid	
	4	0.20-0.05	1.7	Arid	
	5	<0.05	2	Hyper arid	
			EC (ds/m)		Lab analysis, (Ayers & Westcot 1985)
	1	<0.7	1	Low	
	2	0.7-3	1.5	Moderate	
	3	>3	2	High	
			Cl (meq/l)		Lab analysis, (Ayers & Westcot 1985)
IWQI	1	<4.0	1	Low	
	2	4-10	1.5	Moderate	
	3	>10.0	2	High	
			SAR		Lab analysis, (Ayers & Westcot 1985)
	1	0-3	1	V.Low	
	2	3-6	1.2	Low	
	3	6-12	1.5	Moderate	
	4	12-20	1.7	High	
	5	20-60	2	V.High	

Table 5. Ranges and classes of indicators used in study area.

Indicator	Class	Description	Range	Indicator	Class	Description	Range
SQI	1	High quality	< 1.13	MQI	1	High quality	1-1.25
	2	Moderate quality	1.13 – 1.45		2	Moderate quality	1.26-1.50
	3	Low quality	>1.46		3	Low moderate	>1.51
CQI	1	High quality	<1.5	IWQI	1	High quality	<1.0
	2	Moderate quality	1.51-1.81		2	Moderate quality	1-1.41
	3	Low quality	>1.81		3	Low quality	>1.41
VQI	1	High quality	<1.13				
	2	Moderate quality	1.31-1.38				
	3	Low quality	>1.38				

(Kosma *et al.* 1999), (Bakr *et al.* 2012)

Table 6. Types of ESAs and corresponding ranges of ESAI.

number	Type	Subtype	Range of ESAI
1	Non affected	N	<1.17
2	Potential	P	1.17-1.22
3	Fragile	F1	1.23-1.26
	=	F2	1.27-1.32
	=	F3	1.33-1.37
4	Critical	C1	1.38-1.41
	=	C2	1.42-1.53
	=	C3	>1.53

Adopted from Kosma *et al.* (1999).

RESULTS AND DISCUSSION

Adjusted MEDALUS approach

1. Soil Quality Index (SQI)

Scores of soil characteristics used in calculating the value of soil quality index are shown in Table 7, where the moderate textures represented 25.71%, which is L & SiL textures, while the moderately fine textures SCL -CL-SiCL represented 74.28%. The diversity of these textures is due to the nature of the carrier, the distance from it, and the sediments it carries during sedimentation periods. This is what distinguishes sedimentary soils from a wide variation in their texture (Iqbal *et al.* 2005), as a result of the diversity of physiographic units between low basins soils, depression basins, and irrigation levees. The drainage class varied: The moderately drained (M), well-drained (W) and imperfectly drained (F) were 54.28%, 31.42% and 14.28% respectively. The latter was clear, especially, in the soil's series from south of the project. The parent material for the study area was limey and almost flatlands. The low organic matter percentage was 42.85% and moderate by 57.14% due to cultivating many lands with various crops and used in horticulture as well, while leaving other areas due to their high salinity values.

Table 7. Standard and adjusted soil quality index (SQI) and parameters (values and scores).

Type Soil series	Sample	Texture(a)	Parent material	Rock fragment (%)	Slope gradient (%)	Soil depth (cm)	Drainage status	OM (%)	Ec (ds/m)	PH	$CaCO_3$ (%)	Adjusted SQI	description	Standard SQI	Description
MM11 -SiCL	1	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	M (b) (1.4)	1.1 (2)	8.2 (1.8)	7.1 (1.5)	29.4 (2)	1.510	low	1.336	moderate
	2	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	125 (1)	M (1.4)	0.9 (2)	12.3 (1.8)	6.9 (1.5)	31.5 (2)	1.510	low	1.336	moderate
	3	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	M (1.4)	1.2 (2)	7.3 (1.5)	7.8 (1.7)	14.6 (1.7)	1.477	low	1.336	moderate
	4	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	130 (1)	M (1.4)	1.6 (1.5)	4.1 (1.2)	7.4 (1.5)	12.2 (1.7)	1.386	moderate	1.336	moderate
	5	SiCL (1.2)	Limestone (1.7)	< 20 (2	0.8 (1)	128 (1)	M (1.4)	1.5 (1.5)	7.9 (1.5)	7.5 (1.7)	22.4 (2)	1.458	moderate	1.336	moderate
DM97-SiL	6	SiL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	140 (1)	M (1.4)	1.7 (1.5)	3.8 (1.2)	7.4 (1.5)	14.5 (1.7)	1.386	moderate	1.336	moderate

Type Soil series	Sample	Texture$^{(a)}$	Parent material	Rock fragment (%)	Slope gradient (%)	Soil depth (cm)	Drainage status	OM (%)	Ec (ds/m)	PH	$CaCO_3$ (%)	Adjusted SQI	description	Standard SQI	Description
DW95-L	7	SiL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	133 (1)	M (1.4)	0.9 (2)	7.8 (1.5)	7.3 (1.5)	13.7 (1.7)	1.458	moderate	1.336	moderate
	8	SiL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	126 (1)	M (1.4)	1.8 (1.5)	3.5 (1.2)	7.5 (1.5)	11.8 (1.7)	1.386	moderate	1.336	moderate
	9	L (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	130 (1)	$W^{(c)}$ (1.2)	2.0 (1.5)	3.2 (1.2)	7.7 (1.7)	13.5 (1.7)	1.357	moderate	1.264	moderate
	10	L (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	125 (1)	W (1.2)	1.2 (2)	6.9 (1.5)	7.2 (1.5)	11.2 (1.7)	1.410	moderate	1.264	moderate
	11	L (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	125 (1)	W (1.2)	1.7 (1.5)	4.5 (1.5	7.3 (1.5)	12.9 (1.7)	1.370	moderate	1.264	moderate
DM56-SCL	12	SCL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	118 (1)	M (1.4)	1.5 (1.5)	4.8 (1.5	8.1 (1.7)	15.8 (2)	1.432	moderate	1.296	moderate
	13	SCL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	M (1.4)	1.6 (1.5)	3.9 (1.2	7.3 (1.5)	13.4 (1.7)	1.361	moderate	1.296	moderate
	14	SCL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	133 (1)	M (1.4)	1.5 (1.5)	5.4 (1.5	7.1 (1.5)	12.3 (1.7)	1.391	moderate	1.296	moderate
MW5-SiCL	15	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	126 (1)	W (1.2)	2.1 (1.5)	3.3 (1.2	7.4 (1.5)	11.2 (1.7)	1.365	moderate	1.303	moderate
	16	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	135 (1)	W (1.2)	1.6 (1.5)	4.7 (1.5	7.4 (1.5)	14.6 (1.7)	1.395	moderate	1.303	moderate
	17	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	W (1.2)	1.8 (1.5)	3.6 (1.2	7.1 (1.5)	13.3 (1.7)	1.365	moderate	1.303	moderate
DF97-CL	18	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	70 (1.2)	$F^{(d)}$ (1.6)	1.0 (2)	20.5 (2)	6.9 (1.5)	24.5 (2)	1.546	low	1.367	moderate
	19	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	72 (1.2)	F (1.6)	0.9 (2)	18.5 (2)	7.0 (1.5)	28.3 (2)	1.546	low	1.367	moderate
	20	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	70 (1.2)	F (1.6)	0.7 (2)	21.3 (2)	7.6 (1.7)	20.7 (2)	1.566	low	1.367	moderate
MM9-SiCL	21	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	M (1.4)	0.8 (2)	11.4 (1.8)	7.1 (1.5)	32.7 (2)	1.510	low	1.336	moderate
	22	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	115 (1)	M (1.4)	0.7 (2)	14.6 (1.8)	6.8 (1.5)	19.5 (2)	1.510	low	1.336	moderate
	23	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	75 (1.2)	M (1.4)	0.5 (2)	10.8 (1.8)	7.2 (1.5)	20.8 (2)	1.537	low	1.378	moderate
DW44-CL	24	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	128 (1)	W (1.2)	1.8 (1.5)	5.6 (1.5)	7.4 (1.5)	14.6 (1.7)	1.370	moderate	1.264	moderate
	25	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	125 (1)	W (1.2)	2.2 (1.5)	2.9 (1.2)	6.9 (1.5)	11.5 (1.7)	1.340	moderate	1.264	moderate
DM55-L	26	L (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	132 (1)	M (1.4)	1.9 (1.5)	5.8 (1.5)	7.1 (1.5)	12.3 (1.7)	1.391	moderate	1.296	moderate
	27	L (1)	**Limestone**	**< 20 (2)**	**0.8 (1)**	**125 (1)**	**M (1.4)**	**1.6**	**4.0 (1.2)**	**6.8**	14.5 (1.7)	1.361	moderate	1.296	moderate

Type Soil series	Sample	Texture(a)	Parent material	Rock fragment (%)	Slope gradient (%)	Soil depth (cm)	Drainage status	OM (%)	Ec (ds/m)	PH	$CaCO_3$ (%)	Adjusted SQI	description	Standard SQI	Description
			(1.7)					(1.5)		(1.5)					
	28	L (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	116 (1)	M (1.4)	1.6 (1.5)	3.8 (1.2)	7.4 (1.5)	13.9 (1.7)	1.361	moderate	1.296	moderate
DW45-CL	29	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	125 (1)	W (1.2)	2.1 (1.5)	3.5 (1.2)	7.3 (1.5)	11.5 (1.7)	1.340	moderate	1.264	moderate
	30	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	130 (1)	W (1.2)	1.5 (1.5)	7.7 (1.5)	7.8 (1.7)	15.9 (1.7)	1.387	moderate	1.264	moderate
	31	CL (1)	Limestone (1.7)	< 20 (2)	0.8 (1)	127 (1)	W (1.2)	0.9 (2)	12.2 (1.8)	7.4 (1.5)	11.8 (1.7)	1.436	moderate	1.264	moderate
DM115-SiCL	32	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	75 (1.2)	M (1.4)	1.1 (2)	11.4 (1.8)	6.9 (1.5)	20.5 (2)	1.537	low	1.378	moderate
	33	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	120 (1)	M (1.4)	1.6 (1.5)	6.1 (1.5)	7.4 (1.5)	14.7 (1.7)	1.417	moderate	1.336	moderate
DF95-SiCL	34	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	75 (1.2)	F (1.6)	0.6 (2)	30.1 (2)	7.5 (1.7)	30.5 (2)	1.594	low	1.409	moderate
	35	SiCL (1.2)	Limestone (1.7)	< 20 (2)	0.8 (1)	72 (1.2)	F (1.6)	0.5 (2)	27.4 (2)	7.1 (1.5)	26.2 (2)	1.575	low	1.409	moderate

(a)texture= SiCL(silt clay loam), SiL(silt loam),L(loam),SCL(sand clay loam),CL(clay loam).
(b)M= Moderately well drained
(c)W= Well drained
(d) F = Imperfectly drained

The soil ratios were strongly saline (14.28) %, moderately (20.0) %, slightly (34.28) % and v. slightly (31.42) %, so that, the highest salinity values reached 30.1 ds/m in the sample 34 of soil series DF95. The percentage of OM ranged between 0.5% and 2.2%. The high $CaCO_3$ percentage ranged between 11.2 – 32.7%, indicating a moderately-strongly calcareous soils by 37.14 - 62.85%. It is reflected on the soil pH reaction values which ranged between 6.8 and 8.1 as moderately and high alkaline. The variation of values of these characteristics gave a variation in their scores according to the value of each one. Thus the SQI values ranged between 1.340 and 1.594 indicating low quality by 31.83% concentrated in soil series of F imperfectly drained DF97-CL & DF95- SiCL in the south of private study area, with an area of 266.461 km^2. However, the moderate quality constituted 68.16%, which covered most of the project area, with an area of 570.489 km^2. Thus, the standard SQI value was ranged between 1.264 and 1.409 indicating moderate soil quality for all samples. The reason for this discrepancy in the standard and adjusted SQI values is due to the addition of a number of soil characteristics that the sedimentary plain soil characterizes, including the study area.

2. Climate Quality Index (CQI)

The climate quality index includes the rainfall standard, which is less than 280 mm, as the total annual rainfall in the study area was 114.4 mm. Thus its score was equal to 2, the aridity standard was 0.365 and its score was 1.5 according to the proposed parameters in this index. This indicates weak precipitation with high temperatures in the summer months accompanied by a decrease in relative humidity values and elevated evaporation. These conditions contribute to the weak growth of natural vegetation, low organic matter and high salinity values, which leave a negative impact on the rate of land use. Thus, its geometric mean for each study area and all samples are:

$$\mathrm{CQI} = (2 \times 1.5)^{1/2} = 1.732$$

3. Vegetation quality index (VQI)

This index and its parameters are related to the percentage of vegetative cover, the type of cultivated crops, and the degree of their resistance to fire, erosion and drought (Kosmas *et al.* 1999; Table 3).

All the VQI values were greater than 1.38 indicating low quality with a value ranged between 1.414 - 1.681 according to the four-parameter scores of this index (Table 8). Its parameters were of a low-class fire risk and very low quality for each of the Erosion Protection and Drought Resistance standard due to its cultivation with annual cereal crops, many of which were barren lands. It was reflected in the values of the fourth standard of vegetation cover or plant. This was related to the values of NDVI, which ranged between -0.005653 and 0.553080. The relatively high values of NDVI were due to the fact that its lands were cultivated with vegetable crops and some fodder, as well as its use in the horticulture, which represented 31.42% of the samples. The percentage of VC was greater than 40%, while the values of VQI remained low for all study samples.

Table 8. Vegetation quality index (VQI) and parameters (values & scores).

Type soil series	Samp.	Fire risk	Erosion protection	Drought resistance	VC (%) or Plant cover	VQI score	Descrip.
MM11-SiCL	1	Bare land & some annual agriculture crops (1)	Bare land& some annual agriculture crops (2)	Bare land& some annual agriculture crops (2)	4.275 (2)	1.681	low
	2	Bare land (1)	Bare land (2)	Bare land (2)	-3.757 (2)	1.681	low
	3	Bare land (1)	Bare land (2)	Bare land (2)	-3.499 (2)	1.681	low
	4	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.628 (1)	1.414	low
	5	Bare land (1)	Bare land (2)	Bare land (2)	-1.518 (2)	1.681	low
DM97-SiL	6	Annua1agriculture land (1)	Annua1agriculture land (2)	Annua1agriculture land (2)	40.503 (1)	1.414	low
	7	Bare land (1)	Bare land (2)	Bare land (2)	5.622 (2)	1.681	low
	8	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.127 (1)	1.414	low
DW95-L	9	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.502 (1)	1.414	low
	10	Bare land (1)	Bare land (2)	Bare land (2)	0.299 (2)	1.681	low
	11	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.753 (1)	1.414	low
DM56-SCL	12	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	8.914 (2)	1.681	low
	13	Annual agriculture crops &vegetables (1)	Annual agriculture crops& vegetables (2)	Annual agriculture crops& vegetables (2)	43.144 (1)	1.414	low
	14	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	15.905 (1.8)	1.638	low
MW5-SiCL	15	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.705 (1)	1.414	low
	16	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	18.603 (1.8)	1.638	low
	17	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.656 (1)	1.414	low
DF97-CL	18	Bare land (1)	Bare land (2)	Bare land (2)	-4.111 (2)	1.681	low

Type soil series	Samp.	Fire risk	Erosion protection	Drought resistance	VC (%) or Plant cover	VQI score	Descrip.
MM9-SiCL	19	Bare land (1)	Bare land (2)	Bare land (2)	-4.353 (2)	1.681	low
	20	Bare land (1)	Bare land (2)	Bare land (2)	-4.123 (2)	1.681	low
	21	Bare land (1)	Bare land (2)	Bare land (2)	-4.337 (2)	1.681	low
	22	Bare land (1)	Bare land (2)	Bare land (2)	-4.214 (2)	1.681	low
	23	Bare land (1)	Bare land (2)	Bare land (2)	-4.239 (2)	1.681	low
DW44-CL	24	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	18.683 (1.8)	1.638	low
	25	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	41.936 (1)	1.414	low
DM55-L	26	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	17.096 (1.8)	1.638	low
	27	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.313 (1)	1.414	low
	28	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	11.346 (1.8)	1.638	low
DW45-CL	29	Annual agriculture crops (1)	Annual agriculture crops (2)	Annual agriculture crops (2)	40.460 (1)	1.414	low
	30	Bare land (1)	Bare land (2)	Bare land (2)	-3.974 (2)	1.681	low
	31	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	18.842 (1.8)	1.638	low
DM115-SiCL	32	Bare land (1)	Bare land (2)	Bare land (2)	-4.203 (2)	1.681	low
	33	Some annual agriculture crops (1)	Some annual agriculture crops (2)	Some annual agriculture crops (2)	18.822 (1.8)	1.638	low
DF95-SiCL	34	Bare land (1)	Bare land (2)	Bare land (2)	1.252 (2)	1.681	low
	35	Bare land (1)	Bare land (2)	Bare land (2)	1.023 (2)	1.681	low

4. Management quality index (MQI)

The land is classified in this index according to the main use in the study area in general and assessing the management quality or the degree of human-induced stress. According to field observations and local data, the first parameters in this index are land-use intensity (cropland) and low land use intensity (LLUI). Its score is 1, because of the local plant varieties used in the area. The yield depends in many cases on the soil fertility due to the poor use of fertilizers. Along with this, the use of mechanization is very limited and sometimes non-existent, depending on manpower inland service operations. In addition, some areas are left without cultivation. As for the policy class second parameter, its score is 1.5, related to the environmental protection policy for each case of land use. The observations showed that it is of the moderate degree because 25%-75% of the area under partial protection. It also has a link with information related to a percentage of farmers or a percentage of some cultivated areas that did not cover the total area (Babylon Agriculture Directorate 2020), because of the unstable conditions that have passed through the study area many years ago. There were insufficient means of protecting crops from wind erosion, low use of modern irrigation methods, and the lack of scheduling and regulation of the number of crops irrigation. The values of this index and for all the study samples are as follows:

$$\mathrm{MQI} = (1 \times 1.5)^{1/2} = 1.224$$

5. Irrigation water quality index (IWQI)

There are three types of water sources distributed over the entire area of the region, and farmers employ them for their different uses, including irrigation of crops. Their characteristics have varied as shown in Table 9, including water from lined main irrigation channels, especially on the northern side of the project lands (sample 1). Besides, an irrigation water sample for lands from unlined channels branching off the main channel of the project sample 2, referred to the moderate water quality for each of them, as for the lands in the south of the project. Ground water is used for various uses, including land irrigation (sample 3), which is of low quality.

Table 9. Water proprieties, IWQI classes in the study area.

Water sample	EC(ds/m)	Cl (meq l^{-1})	SAR	IWQI	description
1	2.6	3.4	2.5	1.144	Moderate
score	1.5	1.0	1.0		
2	2.9	7.3	2.8	1.310	Moderate
score	1.5	1.5	1.0		
3	11.7	9.5	5.7	1.532	Low
score	2.0	1.5	1.2		

The salinity of the ground water has increased which leads to affecting the quality of the water. Table 10 showed that the moderate IWQI represented 74.38% with values ranged between 1.144 and 1.310 and area of 622.547 km^2, while the low IWQI was 25.61% with a value of 1.532 and area of 214.402 km^2. The quality of the irrigation water was reflected in the quality of soil salinity, so that, it increased in samples of some soils as found in the soil series MM11-SiCL, DF97-CL, MM9-SiCL, DF95-SiCL. The present study showed that the water quality has significant affects the elements, and the response of some plants irrigated with river water appeared higher than the treatments with other water sources (Obead & Jerry 2019). The problem of saline water becomes exacerbated, especially in the lands south of the project, since its groundwater level is close to the soil surface and has a drainage type F (Imperfectly or poorly drained). This may exacerbate the problem of salinity in irrigated areas with arid climates (Dubovy *et al.* 2012), In addition, soil salinity may increase due to the use of saline or untreated irrigation water. The irrigation system and water quality in dry areas accelerate the deterioration of soil properties and raise its salinity to high levels (Díaz *et al.* 2021). Soil properties can be improved using good and moderate water quality. The distributions of indices are depicted in Fig. 3.

ESAI and ESAs types

The distribution and values of ESAI is closely related to the relationship between the parameters used in this index. Table 11 showed its values using the adjusted & standard MEDALUS approach. Adjusted ESAI values ranged between 1.356 and 1.541, indicating that there are two types of lands sensitive to desertification, namely Critical, with an area of 790.78 km^2 and by 94.47%, and the second type is Fragile with an area of 46.17 km^2 and by 5.52%. However, the subtypes, C2-C1-F3-C3 were arranged with percentages of 64.58 - 28.23 - 5.52 - 1.66) % respectively. Similarly, the ESAI values using the standard MEDALUS approach were ranged between 1.264 and 1.409, indicating that all samples of the Critical type were divided between two types, including C1 (6.30) % with an area of 52.7484 km^2 and C2 (93.69)% with an area of 784.2015 km^2. The addition of IWQI led to the appearance of sub-type C3, indicating the effect of saltwater in elevating the susceptibility of land to salinization. It also led to an elevation in the ESAI values, thus upraising its sensitivity to desertification. The use of moderate water quality, especially by a value of 1.144, contributed to improve soil properties, organic matter values, and reducing calcium carbonate values, reflecting in low ESAI values and the appearance of the Fragile type and subtype F3 as in samples 4-8-9-13-15-25- 29-29. On the contrary, the lands of the study area are still ready for sensitivity to desertification, as there are no more potential and none affected species. This is due to the lack of interest in irrigation systems, the poor use of correct irrigation methods, the lack of reclamation processes, as well as insufficient administrative factors to improve the production of cultivated crops.

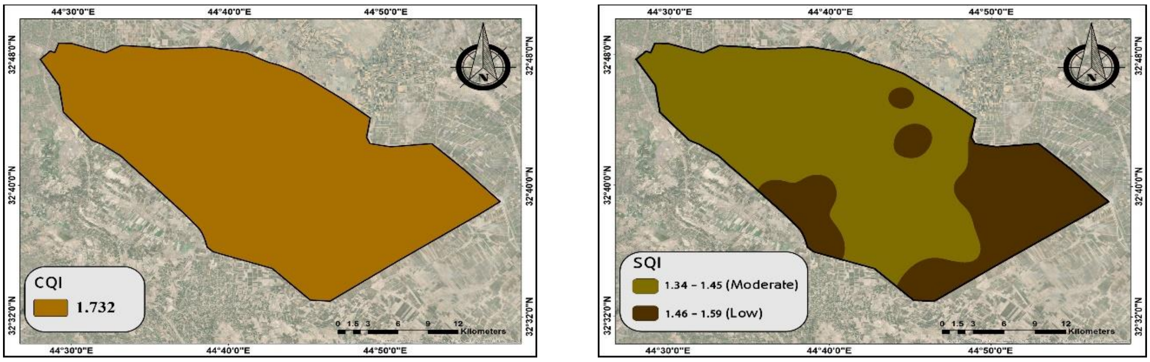
Table 12 and Fig. 4 showed types and subtypes of lands sensitive to desertification and their areas in the study area for the two approaches: adjusted and standard MEDALUS.

Correlation coefficients

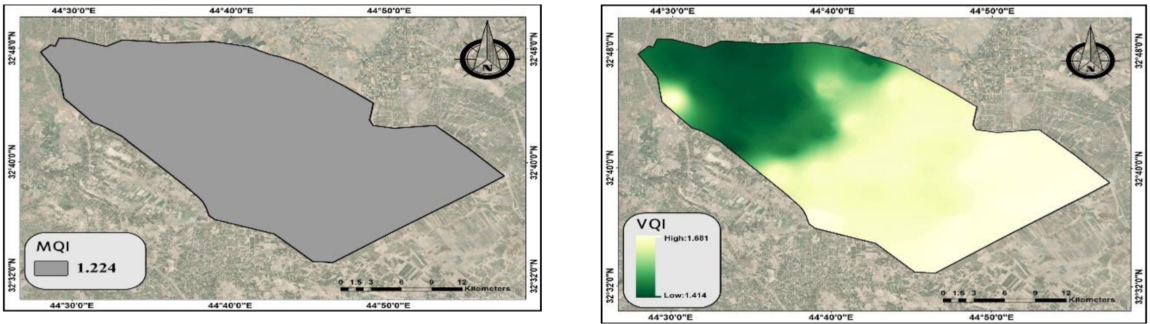
The statistical package for the social sciences SPSS application was used to obtain Pearson's correlation coefficients between indices' values and parameters. The highest positive and significant correlation value was for the SQI with EC - $CaCO_3$ - OM - soil depth - drainage - pH amounted to 0.924 - 0.871 - 0.861 - 0.773 - 0.751 - 0.188, respectively. This indicates the effects of salinity on the other proposed soil characteristics, which was reflected in its value. No correlation was found concerning to the other parameters in this index, because they remained the same for all samples. On the other hand, the VQI value of its correlation with the plant cover was high, strong, and significant (0.99). The IWQI correlation relationship with EC – SAR - Cl was a positive and significant correlation (0.891 - 0.878 - 0.844), respectively. All of the correlations were at 0.01 level, which shows the effect of using irrigation agriculture that may contribute to continuous secondary salinization of the soil in arid and semi-arid regions (Afrasinei *et al*. 2017). However, Table 13 presents the correlation of the adjusted ESAI values with the parameters used in its calculation, exhibiting that the highest positive and significant correlation values were with IWQI –SQI-VQI by 0.901 - 0.861 - 0.852 respectively. The characteristics of irrigation water in the irrigated areas of the middle of the Iraqi sedimentary plain should be taking into account, because of its strong correlation and impact on the degree of sensitivity of its lands to desertification.

Table 10. Irrigation water quality index (IWQI) and parameters (values and scores).

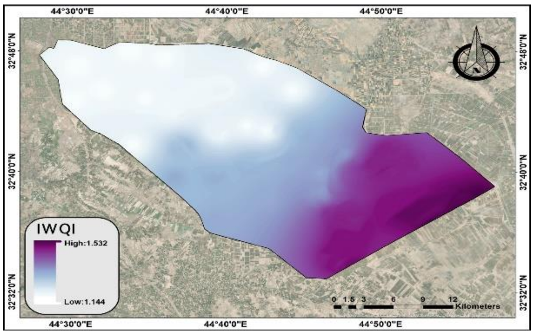
Soil Types	Samples	EC (ds/m)	Cl (meq/l)	SAR	I WQI	description	Soil Types	Samples	EC (ds/m)	Cl (meq/l)	SAR	IWQI	description
	1	2.9	7.3	2.8				21	15.7	9.5	5.7		
		1.5	1.5	1.0	1.310	moderate			2.0	1.5	1.2	1.532	low
	2	15.7	9.5	5.7			MM9-SiCL	22	2.9	7.3	2.8		
		2	1.5	1.2	1.532	low			1.5	1.5	1.0	1.310	moderate
MM11-SiCL	3	2.6	3.4	2.5				23	2.9	7.3	2.8		
		1.5	1.0	1.0	1.144	moderate			1.5	1.5	1.0	1.310	moderate
	4	2.6	3.4	2.5				24	2.9	7.3	2.8		
		1.5	1.0	1.0	1.144	moderate	DW44-CL		1.5	1.5	1.0	1.310	moderate
	5	2.6	3.4	2.5				25	2.6	3.4	2.5		
		1.5	1.0	1.0	1.144	moderate			1.5	1.0	1.0	1.144	moderate
	6	2.6	3.4	2.5				26	2.9	7.3	2.8		
		1.5	1.0	1.0	1.144	moderate			1.5	1.5	1.0	1.310	moderate
DM97-SiL	7	2.6	3.4	2.5			DM55-L	27	2.6	3.4	2.5		
		1.5	1.0	1.0	1.144	moderate			1.5	1.0	1.0	1.144	moderate
	8	2.6	3.4	2.5				28	2.6	3.4	2.5		
		1.5	1.0	1.0	1.144	moderate			1.5	1.0	1.0	1.144	moderate
	9	2.6	3.4	2.5				29	2.6	3.4	2.5		
		1.5	1.0	1.0	1.144	moderate			1.5	1.0	1.0	1.144	moderate
DW95-L	10	15.7	9.5	5.7			DW45-CL	30	2.9	7.3	2.8		
		2	1.5	1.2	1.532	low			1.5	1.5	1.0	1.310	moderate
	11	2.9	7.3	2.8				31	15.7	9.5	5.7		
		1.5	1.5	1.0	1.310	moderate			2	1.5	1.2	1.532	low
	12	2.9	7.5	2.8				32	2.9	7.3	2.8		
		1.5	1.5	1.0	1.310	moderate	DM115-SiCL		1.5	1.5	1.0	1.310	moderate
DM56-SCL	13	2.6	3.4	2.5				33	2.6	3.4	2.5		
		1.5	1.0	1.0	1.144	moderate			1.5	1.0	1.0	1.144	moderate
	14	2.9	7.3	2.8				34	15.7	9.5	5.7		
		1.5	1.5	1.0	1.310	moderate	DF95-SiCL		2	1.5	1.2	1.532	low
	15	2.6	3.4	2.5				35	15.7	9.5	5.7		
		1.5	1.0	1.0	1.144	moderate			2	1.5	1.2	1.532	low
MW5-SiCL	16	2.9	7.3	2.8									
		1.5	1.5	1.0	1.310	moderate							
	17	2.6	3.4	2.5									
		1.5	1.0	1.0	1.144	moderate							
	18	15.7	9.5	5.7									
		2	1.5	1.2	1.532	low							
DF97-CL	19	15.7	9.5	5.7									
		2	1.5	1.2	1.532	low							
	20	15.7	9.5	5.7									
		2	1.5	1.2	1.532	low							



CQI Adjusted SQI



MQI VQI



IWQI

Fig. 3. Indices distribution in the study area.

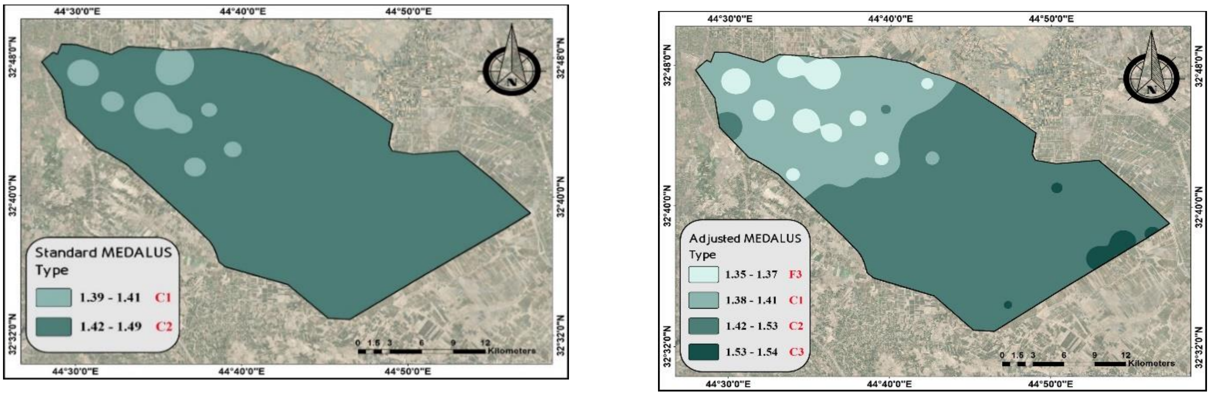
Table 11. ESAI and types of ESAs in Almussiab project (adjusted and standard).

Soil Types	Samples	SQI	CQI	VQI	MQI	IWQI	Adjusted ESAI	ESAs		Standard ESAI	ESAs	
								Type	Subtype		Type	Subtype
MM11-SiCL	1	1.510	1.732	1.681	1.224	1.310	1.477	critical	C_2	1.477	critical	C_2
	2	1.510	1.732	1.681	1.224	1.532	1.524	critical	C_2	1.477	critical	C_2
	3	1.477	1.732	1.681	1.224	1.144	1.431	critical	C_2	1.447	critical	C_2
	4	1.386	1.732	1.414	1.224	1.144	1.365	fragile	F_3	1.414	critical	C_1
	5	1.458	1.732	1.681	1.224	1.144	1.428	critical	C_2	1.447	critical	C_2
DM97-SiL	6	1.386	1.732	1.414	1.224	1.144	1.365	fragile	F_3	1.414	critical	C_1
	7	1.458	1.732	1.681	1.224	1.144	1.428	critical	C_2	1.477	critical	C_2
	8	1.386	1.732	1.414	1.224	1.144	1.365	fragile	F_3	1.414	critical	C_1
DW95-L	9	1.357	1.732	1.414	1.224	1.144	1.360	fragile	F_3	1.395	critical	C_1

	10	1.410	1.732	1.681	1.224	1.532	1.504	critical	C_2	1.456	critical	C_2
	11	1.370	1.732	1.414	1.224	1.310	1.400	critical	C_1	1.395	critical	C_1
DM56-SCL	12	1.432	1.732	1.681	1.224	1.310	1.462	critical	C_2	1.465	critical	C_2
	13	1.361	1.732	1.414	1.224	1.144	1.360	fragile	F_3	1.403	critical	C_1
	14	1.391	1.732	1.638	1.224	1.310	1.446	critical	C_2	1.456	critical	C_2
MW5-SiCL	15	1.365	1.732	1.414	1.224	1.144	1.361	fragile	F_3	1.405	critical	C_1
	16	1.395	1.732	1.638	1.224	1.310	1.447	critical	C_2	1.458	critical	C_2
	17	1.365	1.732	1.414	1.224	1.144	1.361	fragile	F_3	1.405	critical	C_1
DF97-CL	18	1.546	1.732	1.681	1.224	1.532	1.532	critical	C_3	1.485	critical	C_2
	19	1.546	1.732	1.681	1.224	1.532	1.532	critical	C_3	1.485	critical	C_2
	20	1.566	1.732	1.681	1.224	1.532	1.535	critical	C_3	1.485	critical	C_2
MM9-SiCL	21	1.510	1.732	1.681	1.224	1.532	1.524	critical	C_2	1.477	critical	C_2
	22	1.510	1.732	1.681	1.224	1.310	1.477	critical	C_2	1.477	critical	C_2
	23	1.537	1.732	1.681	1.224	1.310	1.483	critical	C_2	1.488	critical	C_2
DW44-CL	24	1.370	1.732	1.638	1.224	1.310	1.441	critical	C_2	1.447	critical	C_2
	25	1.340	1.732	1.414	1.224	1.144	1.356	fragile	F_3	1.395	critical	C_1
DM55-L	26	1.391	1.732	1.638	1.224	1.310	1.446	critical	C_2	1.456	critical	C_2
	27	1.361	1.732	1.414	1.224	1.144	1.360	fragile	F_3	1.403	critical	C_1
	28	1.361	1.732	1.638	1.224	1.144	1.401	critical	C_1	1.456	critical	C_2
DW45-CL	29	1.340	1.732	1.414	1.224	1.144	1.356	fragile	F_3	1.395	critical	C_1
	30	1.387	1.732	1.681	1.224	1.310	1.452	critical	C_2	1.456	critical	C_2
	31	1.436	1.732	1.638	1.224	1.532	1.501	critical	C_2	1.447	critical	C_2
DM115-SiCL	32	1.537	1.732	1.681	1.224	1.310	1.483	critical	C_2	1.488	critical	C_2
	33	1.417	1.732	1.638	1.224	1.144	1.412	critical	C_1	1.467	critical	C_2
DF95-SiCL	34	1.594	1.732	1.681	1.224	1.532	1.541	critical	C_3	1.496	critical	C_2
	35	1.575	1.732	1.681	1.224	1.532	1.537	critical	C_3	1.496	critical	C_2

Table 12. Areal coverage for ESAI in the study area using the adjusted & standard MEDALUS approach.

Adjusted				**Standard**	
Type	Subtype	Area (km^2)	%	Area(km^2)	%
F	F3	46.17	5.52	-	-
C	C1	236.35	28.23	52.75	6.30
	C2	540.56	64.58	784.20	93.69
	C3	13.87	1.66	-	-



A **B**

Fig. 4. Types of ESAs: A: Standard MEDALUS; B: Adjusted MEDALUS.

Table 13. Pearson's correlation coefficients between adjusted ESAI and its parameters.

	Adjusted ESAI	SQI	CQI	VQI	MQI	IWQI
Adjusted ESAI	1					
SQI	0.861**	1				
CQI	.b	.b	1			
VQI	0.852**	0.710**	.b	1		
MQI	.b	.b	.b	.b	1	
IWQI	0.901**	0.695**	.b	0.619**	.b	1

**. Correlation is significant at the 0.01 level (2-tailed).

b. Can not be computed because at least one of the variables is constant.

CONCLUSION

The application of the adjusted MEDALUS approach, in which parameters were added to SQI, gave an indication of the soil characteristics in the study area and the appearance of moderate and low quality. Hence, a high correlation was observed for the values of this index with the characteristic of soil salinity, which is one of the main problems in the lands of the Iraqi sedimentary plain in general, including the study area, with the percentages of $CaCO_3$, and OM, and the moderate soil quality prevailed in the standard approach of MEDALUS. The prevalence of low VQI was also evident due to factors with on help to have a good vegetation as well as low values of other parameters to this index. The addition of IWQI to the adjusted approach for MEDALUS which was between moderate quality prevailing and low quality, has a role in the variation of ESAs types, which was in two types: Critical with prevalent (71.42) %, and subtypes such as C1, C2, C3, as well as Fragile F3 types, at a rate of 28.57%. As for the standard approach, its application led to the appearance of one type of land sensitive to desertification in the study area, which is Critical C1 and C2. The addition of parameters to SQI and the expansion of the land sensitivity indices to desertification by adding IWQI showed the sensitivity of the critical and fragile project lands, hence the lands of the study area will remain ready for desertification, since there are no potential and none-affected species. It is especially true if the necessary measures are not taken in an agricultural environment which needs more attention by the relevant authorities. It is particularly in the field of improving the quality of irrigation water and vegetation cover, due to their direct and indirect effects on the soil quality. Thus, it contributes to the desertification of lands, with the importance of emphasizing the need for proper planning and management of the region resources as well as their environmental protection for the proper use of land and sustainable development.

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