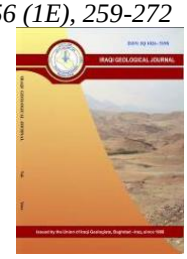
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Desertification Assessment for the Marshes Region Using Soil Quality Indicators, Southern Iraq

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Abstract

The study aims to conduct an assessment of desertification in the marshlands of southern Iraq by using eight soil indicators. The study area is part of the governorates of Amarah, Basrah and Nasiriyah, with an area of about 27,989 km^2. The Mediterranean model of desertification and land use model (MEDALUS) was adopted for the assessment of the soil quality indicators. Satellite image processing of Landsat images and ArcGIS v.10.7 programs were used to analyze different data and produce the soil quality index and maps for evaluating marshes area desertification. This study found that the marshes area is divided into two categories. The first category represented about 3.52%, covering a small area of 984 km^2 and classified as non-sensitive to desertification. While the second category represents about 96.48%, covers most of the study area and involves 27.005 km^2 and consider sensitive to desertification.

Keywords: Soil quality index; Environment; GIS; Desertification; MUDALUS; Southern Iraq

1. Introduction

Desertification is one of the world's most serious environmental issues, resulting in land degradation and a lack of biological activity on land. This phenomenon occurs as a result of a decrease in flora and water in high-temperature locations, as well as an increase in salinity (Zwain et al., 2021). Desertification was described as land deterioration in arid, semi-arid, and dry sub-humid areas caused by a variety of factors, including climatic fluctuations and human activities at the Rio de Janeiro-Brazil Summit in 1992 (Abbas and Mahdi, 2019). The Iraqi Marshland is considered to be one of the most critical marshlands in the world. It is represented the largest ecosystem in Eastern and Western Asia and is considered a non-marine Marshland with Endemic Bird area status and the main habitat for Gulf's freshwater fish.

The marshland is home to 500,000 native Marsh Arabs (Felix and Ottah, 2019). The area of the marshes began to shrink since the fifties of the last century due to climatic factors and the intervention of communities from building dams in Turkey, Syria and Iraq, and drying areas for political reasons or using improper agricultural methods in addition to the oil drilling operations. This caused the destruction of the natural environment and the increase of decertified areas, the devastation of life and the ecosystem in the region, and a rise in dust storms (Partow, 2001). Consequently, the risk may expand to economic collapse, disruption of nature and life and depletion of essential water resources (Gorin et al., 2019). Key factors related to desertification include drought, deforestation, wildfires, soil erosion, over-use of

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natural resources such as land, surface water, and groundwater, and animal overgrazing of vegetation (Pravalie et al., 2017). This challenge is significantly increasing in negative environmental, ecological and economic impact in many countries due to the long term inappropriate management of Soil, water, fertility deterioration, climate change, and other factors (Hamad et al., 2021; Rasheed and Al-Ramahi, 2021). Soil quality has been described primarily to understand desertification, the natural influences, land use, human activities, and agricultural management that can impact spatial disparities in soil quality(Brevik et al., 2015). There is no standardized evaluation technique for evaluating soil quality since there are so many variables that might impact it. Many studies were conducted to evaluate desertification sensitivity employing soil quality indicators.

Alagele and Hamid (2021) analyzed the environmental sensitivity of desertification using the MEDALLUS model in GIS for the Al-Maimuna project in southern Iraq and the results showed that the Soil was classified as medium to low quality (Hamad et al., 2021). Uzuner and Dengiz (2020) also detect soil and land degradation by producing desertification maps on Turkish lands using the soil quality index as an important indicator. The results showed that 60% of the total area is fragile and critical, while about 12% of Turkish lands are unaffected by the risk of desertification (Uzuner and Dengiz, 2020). Gad and Lotfy (2010) determined the environmental sensitivity to desertification in Egypt's northern coastal region using GIS and remote sensing. The findings indicated that the northern shore of Egypt is extremely vulnerable to desertification (Gad and Lotfy, 2008). Qadir and Azeez (2020) evaluated the state of desertification of dry lands in some northern regions in Iraq and the results showed that the lands are divided into a category of moderate quality and occupy 95% of the area and the second is of low quality and constitutes 5% of the studied area (Qadir and Azeez, 2020). The development of a sensitivity map for desertification in northern Iran was studied using the MEDALUS model, and the results indicated that 39.39% of the study area is highly sensitive to desertification, 2.13% has moderate sensitivity, 2.43% have low sensitivity, and 6.05% are not sensitive to desertification (Sobhani and Khosravi, 2015). The current study aims to investigate desertification in the marshlands of southern Iraq employing eight soil indicators, by using MEDALUS and remote sensing techniques. The research is a fundamental building block of the process of soil quality index development, where the research can be leveraged in desertification monitoring and treatment, it’s one of competitive and requested study.

2. Materials and Methods

2.1. Study Area

The southern Mesopotamian marshes lie in the southern part of Iraq. They extend over three of Iraq’s provinces, Amarah, Basrah, and Nasiriyah, and occupy more than 27898 km^2. Iraqi Marshland is along latitudes 29.55˚ to 32.55˚N and longitudes 46.1˚ to 48.1˚E (Fig. 1). The Marshland is made up of three structures, namely, the Al-Hammar, Central Marshes, and Al-Hawizeh. Al-Hammar Marsh is located towards the south of the Euphrates River and extends from Nasiriyah to Basrah in the east. The Central marshes are located in the mid of the Euphrates and Tigris rivers. Al-Hawizeh Marsh is situated towards the south of Basrah and the northern part of Al-Amarah (Felix and Ottah, 2019). The climate of the marshes region is described within the Iraqi alluvial plain, which is characterized by hot and humid summers and cold winters with rainfall, The temperature ranges between 35˚-50˚in the summer, and in January, it reaches 0°C in the winter in the northeastern winds prevail in the marshes and in the summer the northwest winds blow over the marshes (Hashim et al., 2019; Khosravi et al., 2019). While the average rainfall is less than 25 mm/year (Al-Lami et al., 2021).

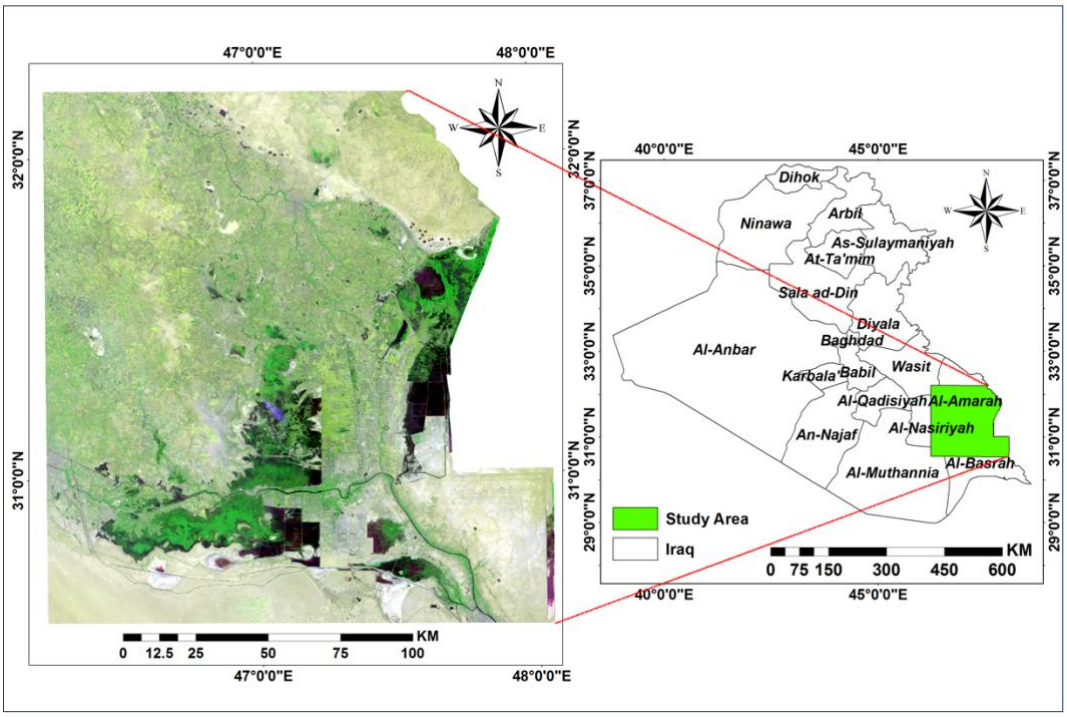


Fig. 1. Location of the study area, the marshes of southern Iraq

2.2. Soil Quality Indicator

The soil quality is calculated by providing a measure of the natural quality of the physical environment and the pressure of human-induced desertification (Qadir and Azeez, 2020). The Soil in dry semi-arid, and arid regions affect biomass and consider the dominant factor in the ecosystem (Kadović et al., 2016). The soil quality index is related to nine parameters, as shown in Fig. 2.

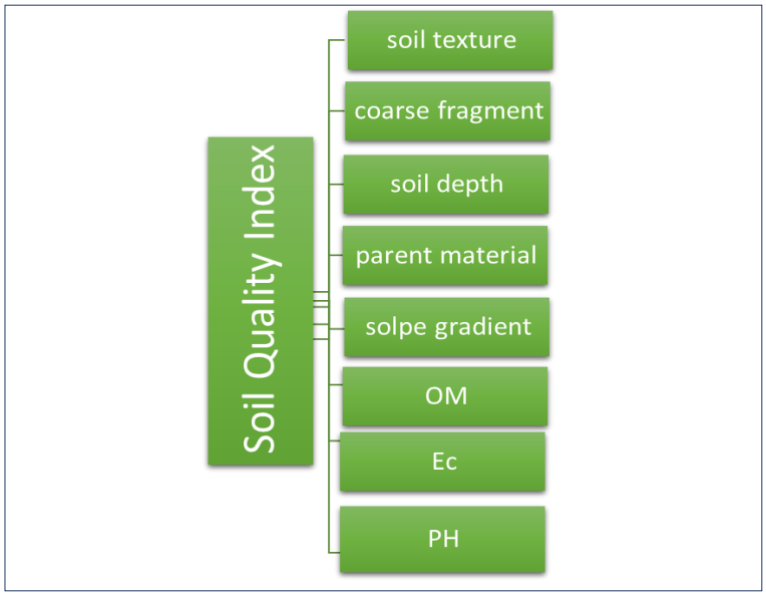


Fig. 2. Different elements are used to assess soil quality indexes

Soil data were obtained from the International Soil Reference and Information Centre (ISRIC), which includes parent material, carbon organic matter, electrical conductivity, soil depth, and coarse fragmentation. In contrast, the Food and Agriculture Organization (FAO) provides soil texture data.

Regression slope gradient obtained from Dem Data provided by the digital elevation satellite affiliated. The classification is based on an average value ranging from 1 to 2 within the model for individual indicators. This values give relative vulnerability to sensitivity, individual factors for their indicators are described in Table 1.

Table 1. Structure of range and weight index of the soil quality index according to MEDALUS method (Qadir and Azeez, 2020)

Soil texture class	**Description**	**Texture**	**Index**
1	Good	L, SCL, SL, LS,CL	1
2	Moderate	SC, SiL, SiCL	1.2
3	Poor	Si, C, SiC	1.6
4	Very poor	S	2
Soil parent material class	**Description**	**parent material**	**Index**
1	Good	Shale, schist, basic, ultra-basic, Conglomerates. Limestone, marble, granite, Rhyolite, Ignibrite, neiss, siltstone, sandstone. Marl, Pyroclastic.	1
2	Moderate		1.7
3	Poor		2
Soil slope class	**Description**	**Slope%**	**Index**
1	Very gentle to flat	>6	1
2	Gentle	6-18	1.2
3	Steep	18-35	1.5
4	Very steep	>35	2
Soil depth class	**Description**	**Depth (cm)**	**Index**
1	Deep	>75	1
2	Moderate	75-30	1.33
3	Shallow	15-30	1.66
4	Very shallow	<15	2
Soil coarse fragment class	**Description**	**coarse fragment(cm)**	**Index**
1	Very stone	>60	1
2	Stony	20-60	1.3
3	Bare to lightly stony	<20	2
Soil carbon organic matter Class	**Description**	**Organic matter (%)**	**Index**
1	Very good	>3	1
2	Good	2-3	1.2
3	Moderate	1-2	1.5
4	Poor	0.5-1	1.7
5	Very poor	<1	2
Soil electrical conductivity class	**Description**	**EC (mmhos.cm-1)**	**Index**

1	Very low	>4	1
2	low	4-8	1.2
3	Moderate	8-16	1.4
4	Almost high	16-32	1.6
5	High	32-64	1.8
6	Very high	<64	2

Soil pH	Description	Soil pH	Index
1	Neutral	6.6 – 7.3	2
2	Slightly alkaline	7.4 – 7.9	1
3	Moderately alkaline	7.9 – 8.4	1.5
4	Strongly alkaline	8.4 – 9.0	1.7
5	Very strongly alkaline	> 9.0	2

2.3. Mapping Soil Quality Index (SQI)

Eight soil parameters related to water availability and erosion resistance were considered according to the methodology. Weighting factors were assigned for each category of the studied parameters according to Adeel et al. (2005). The SQI was calculated based on the combination of different sub-indicators indicated in Equation (1).

$$SQI = (IP*IT*ID*IS*IEC*IPH*IOCM*ICF)^{1/8} \quad (1)$$

Where IP index parent material, IT index texture, ID index soil depth, IS index slope gradient, IEC index electrical conductivity, IPH index pH, IOCM index carbon organic matter, and ICF index coarse fragmentation. According to the categories shown in Table 2, the classification demonstrates the assigned indexes for different categories of each parameter.

Table 2. Structure of range and weight index soil quality indicator according (Afifi et al., 2010)

Class	Description	Range
1	High sensitive	<1.13
2	Moderate sensitive	1.13-1.45
3	Low sensitive	>1.46

3. Results and Discussion

3.1. Soil Quality Criteria

3.1.1. Soil texture

The types of soil texture and area size in the study area are represented in Table 3 and Fig. 3. Soil texture is divided into three categories: good, medium, and poor.

Table 3. Distribution of soil texture classes and assigned scores in the study area

Type	Score	Area Km^2	Area %	Class
Loam , Loam sand	1	4323.4	15.464	Good
Clay -Lomam, clay	1.66	23375.7	83.521	Moderate
Sand	2	289.9	1.015	Poor
Total		27989	100	

The good areas that are least susceptible to desertification represent 15.464%, with an area of about 4323.4 km^2 getting a score of 1.00 on the desertification index. While 83.521%, with an area of about 23375.7 km^2, gives a value of 1.66 on the desertification index, representing medium sensitivity to desertification. However, 1.015% of the area represents the spread of sandy soil and signifies poor with an area of 289.9 km^2. This area is very sensitive to desertification, with a value of 2.00. It was found that the area whose texture is clay-lomam, clay is moderately sensitive to desertification.

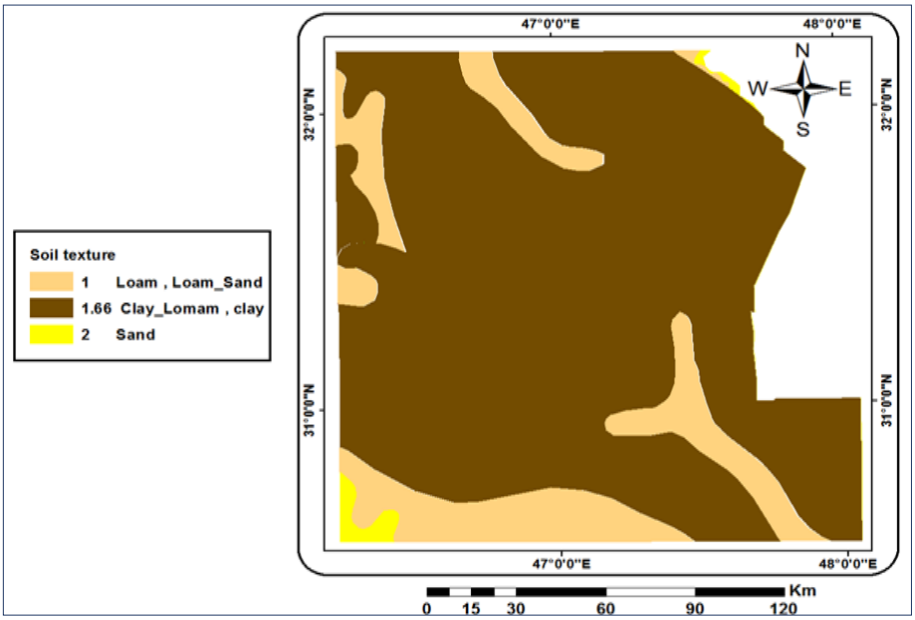


Fig. 3. Soil texture classes and scores of the southern Iraqi Marshland

3.1.2. Soil Parent material

The Soil Parent material is an important transaction to determine the sensitivity, as shown in Table 4 and Fig. 4, the Soil Parent material is divided into three cases coherent, modern, and soft to friable. The coherent area represented 34.304% with an area of 9601.365 km^2, resulting in 1.00 of the sensitivity index. While 0.316%, with an area of about 88.464 km^2, gave a value of 1.33 on allergies and medium for desertification sensitivity. 61.814% of the area is soft to friable, with an area of 17301 km^2 is very sensitive to desertification, giving a value of 2.00 and representing the Solonghaks soil spread areas which are very critical areas for desertification. The study found that most areas are formed of soil-type solonghaks, which are very sensitive to desertification.

Table 4. Distribution of Soil Parent material classes and assigned scores in the study

Type	Score	Area Km^2	Area %	Class
Water bodies	0	998.171	3.566	
Fluvisols	1.00	9601.365	34.304	Coherent
Kastanozem	1.33	88.464	0.316	Moderately
Solonghaks	2.00	17301	61.814	Soft to friable
Total		27989	100	

3.1.3. Soil depth

The depth of the Soil is one of the most critical criteria in determining the extent of desertification. The little soil depth represented greater sensitivity to desertification and vice versa. The soil depth results

are illustrated in Table 5 and Fig. 5. Very deep Soil represents 0.05% of the study area on an area of 14.32 km^2, where it is represented by a score of 1.00 on the sensitivity index.

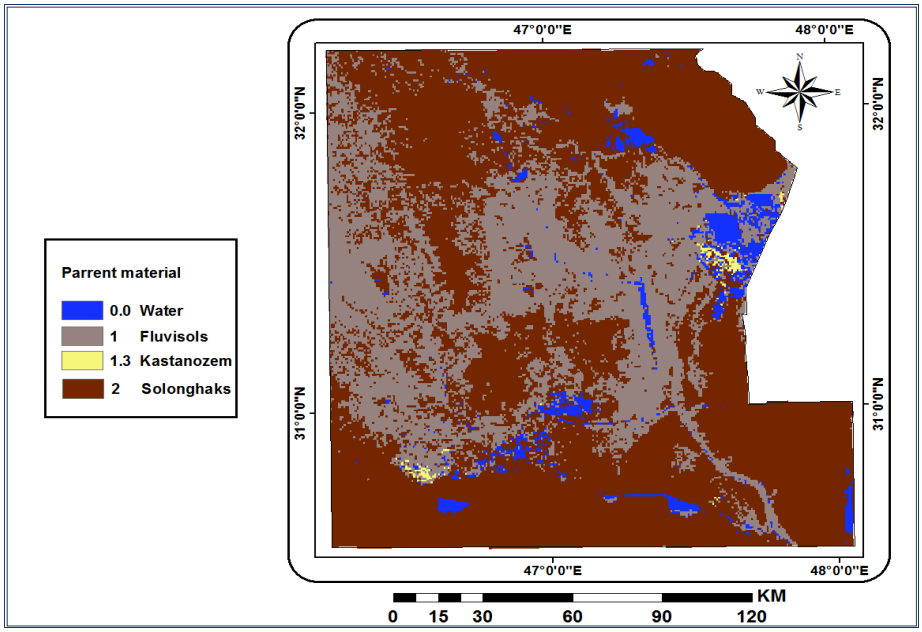


Fig. 4. Soil Parent material classes and scores of the southern Iraqi Marshland

The areas of moderate depth cover 23.74% with an area of 6647.45 km^2 of the study area, and it was given a score of 1.33 on the sensitivity index. While the area of shallow depth cover about 70.3% represents the area of 19672.46 km^2, with a score of 1.66 being more susceptible to desertification than soils of great depth. The very thin areas are estimated at 5.91% with an area of 1654.77 km^2 of the study area and take a degree of 2.00 on the desertification index.

Table 5. Distribution of soil depth classes and assigned scores in the study area.

Type	Score	Area Km^2	Area %	Class
>75	1.00	14.32	0.05	Very deep
30-75	1.33	6647.45	23.74	Moderately deep
30-15	1.66	19672.46	70.3	Shallow
<15	2.00	1654.77	5.91	Very thin or water bodies
Total		27989	100	

Fig. 5. Soil depth classes and scores of the southern Iraqi Marshland

3.1.4. Slope gradient

The slope of the soil surface results is illustrated in (Table 6 and Fig 6). The slope of the soil surface is divided into three categories: gentle, steep, and very steep. Gently sloping soils with a surface slope of less than 5% are less prone to desertification, which represented 72 .09% with an area of about 2077.67 km^2 and get 1.00 on the sensitivity index. While the steep by 0.31% is located in the undulating region between 6 and 10% and is prone to a medium degree of desertification index and extends over an area of 86.49 km^2 of the study area and was given a score of 1.33 on the sensitivity index. As for the rest of the study area, it is classified as Soil with a very steep surface, ranging between 11 and 35%, which is more prone to desertification, covering about 0.02% of the study area with an area of 3.77 km^2 and it has a score of 1.66 on the desertification index. It was found that most of the area has a slope of less than 5%, which is not sensitive to desertification.

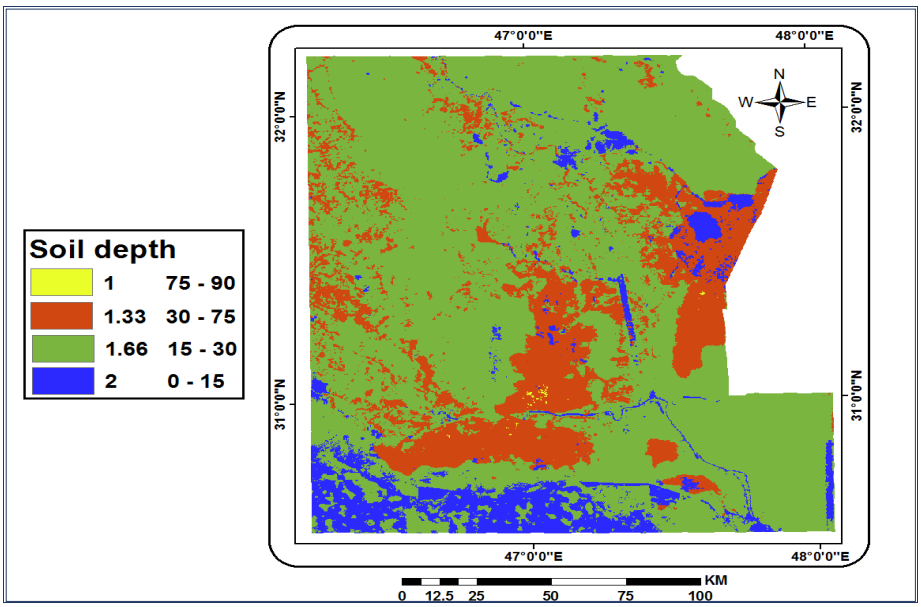


Table 6. Distribution of Slope gradient classes and assigned scores in the study area.

Type	Score	Area Km^2	Area %	Class
Water bodies to flat	0	7721.07	27.58	flat
<5%	1.00	20177.67	72.09	gentle
6 - 10%	1.33	86.49	0.31	steep
11 - 35%	1.66	3.77	0.02	very steep
Total		27989	100	

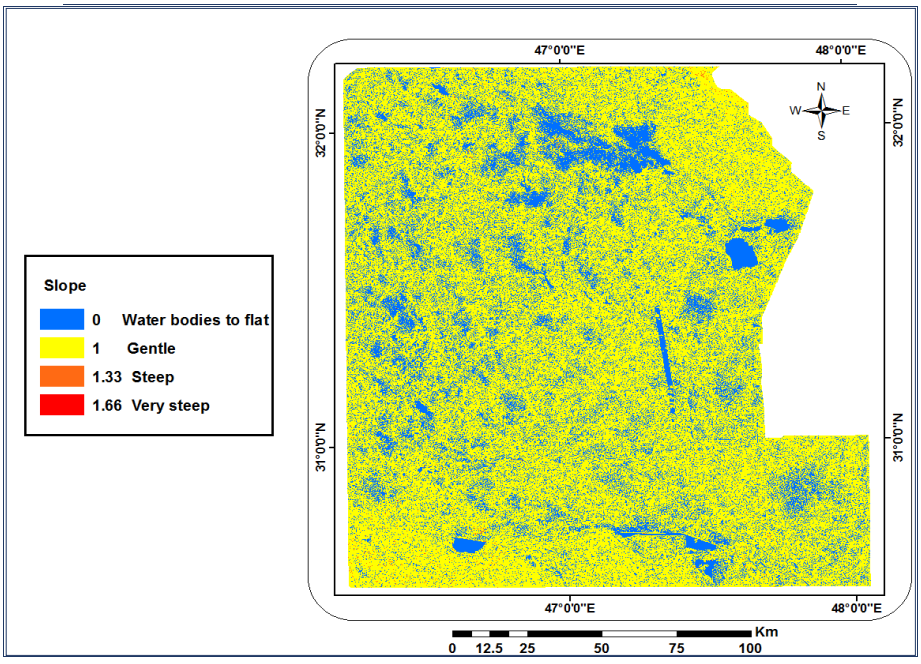


Fig. 6. Slope gradient classes and scores of the southern Iraqi Marshland

3.1.5. Coarse fragment

One of the most important factors in determining the susceptibility to desertification is the coarse part of the Soil, as shown in Table 7 and Fig 7 where it is divided into three sections: very stony, stony, and bare to lightly stony. Soils with coarse particles greater than 60 are less prone to desertification,

represened15.25% of the study area with about 4269.45 km^2 and obtaining 1.00 on the desertification sensitivity index. While the stony Soil, whose ratio is between 20 and 60, extends by about 40.81% and covers an area of about 11423.52 km^2 from the study area, obtaining 1.33 on the sensitivity index and the average vulnerability to desertification. The rest of the region is barren, and few coarse particles are less than 20 where it extends over an area of 11290.66 km^2, which is about 40.34% of the study area, obtaining 2.00 on the desertification index, and it is more susceptible to desertification than the rest of the regions.

Table 7. Distribution of Coarse fragment classes and assigned scores in the study area

Type	Score	Area Km^2	Area %	Class
Water bodies	0	1005.37	3.59	
>60	1.00	4269.45	15.25	Very stony
20-60	1.33	11423.52	40.81	Stony
<20	2.00	11290.66	40.34	Bare to lightly stony
Total		27989	100	

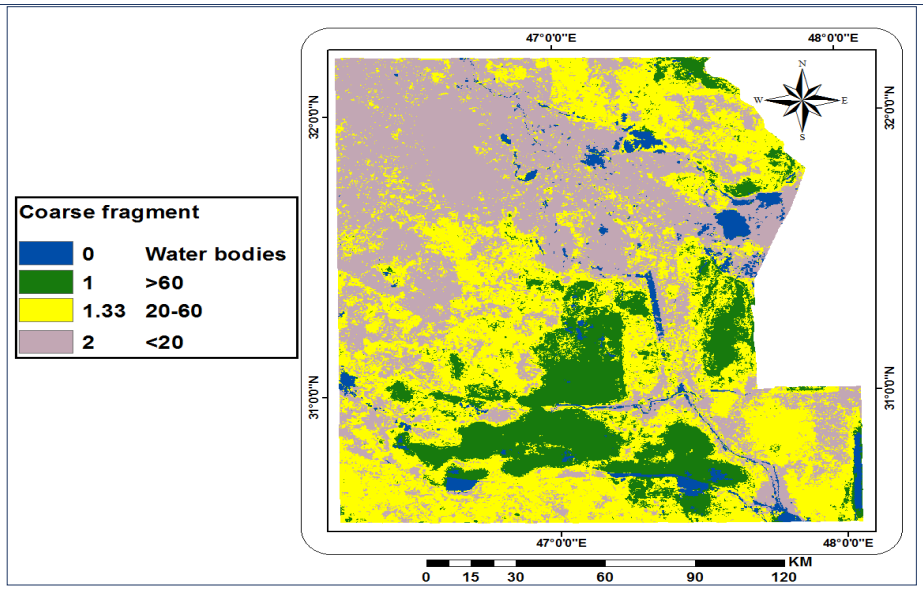


Fig. 7. Coarse fragment classes and scores of the southern Iraqi Marshland

3.1.6. soil carbon organic matter

When measuring a soil's vulnerability to desertification, the amount of organic carbon in the Soil is crucial. The details in Table 8 and Fig. 8 represent the types, degrees, and areas of organic carbon in the study area. The organic carbon is very good as it represents 3% less susceptible to desertification, covers an area of 633.26 km^2 about 2.26% of the study area, and was given a degree of 1.00 on the desertification sensitivity scale.

Table 8. Distribution of Soil carbon organic matter classes and assigned scores in the study area

Type	Score	Area Km^2	Area %	Class
>3	1.00	633.26	2.26	Very good
0.5-3	1.55	4102.97	14.66	Moderate
>0.5	2.00	23252.77	83.08	Very poor
Total		27989	100	

The area whose sensitivity is medium takes a degree of 1.55 on the desertification scale 0.5-3% and spreads over an area of 4102.97 km^2 with about 14.66% of the study area. The area that is very poor in organic carbon, as it contains less than 0.5% is more susceptible to desertification and takes a degree of 2.00 on the scale of desertification sensitivity. It represents 23252.77 km^2 with 83.08% of the study area.

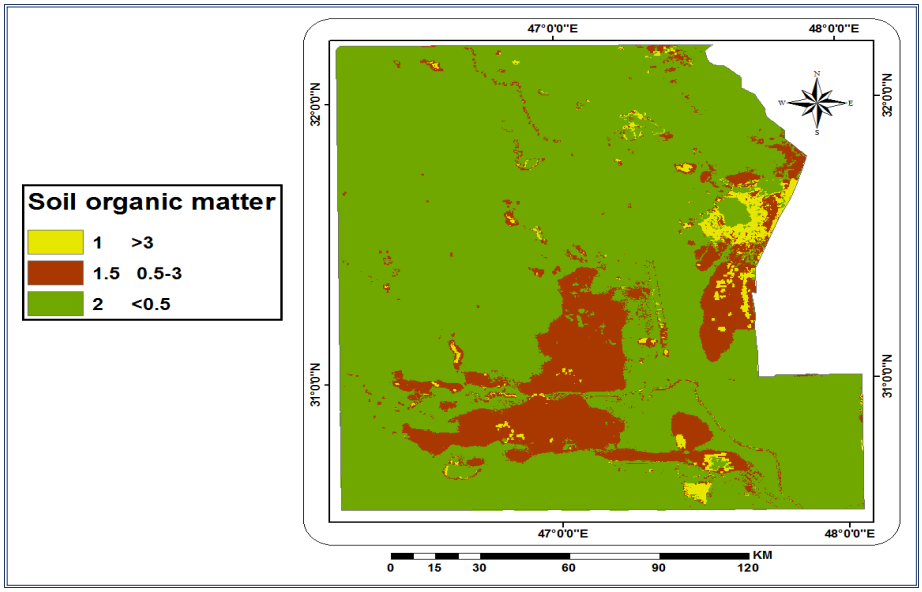


Fig. 8. Soil carbon organic matter classes and scores of the southern Iraqi Marshland

3.1.7. Soil electrical exchange

As demonstrated, soil electrical exchange is one of the most critical elements in determining desertification sensitivity (Table 9 and Fig. 9). Soil that is very high for electrical exchange spreads over an area of 2798.9 km^2 with about 10% of the study area, which takes a value of 1.00 on the scale of desertification sensitivity and is less prone to desertification. The area that is high in electrical exchange spreads over an area of 4758.13 km^{2,} with about 17% of the study area taking a value of 1.33 on the desertification scale. The area that is moderate directors of electrical exchange takes value of 1.66 on the desertification scale and is spread over an area of 8116.81 km^2 by about 29% of the study area. While the areas most prone to desertification have very weak electrical exchange and spread over an area of 11195.6 km^2, about 40 % of the study area takes a value of 2.00 on a scale of sensitivity to desertification.

Table 9. Distribution of Soil electrical exchange classes and assigned scores in the study area

Type	Score	Area Km^2	Area %	Class
Water bodies	0	1119.56	4	
<32	1.00	2798.9	10	Vere high
18-32	1.33	4758.13	17	High
18-8	1.66	8116.81	29	Moderate
<8	2.00	11195.6	40	Vere low
Total		27989	100	

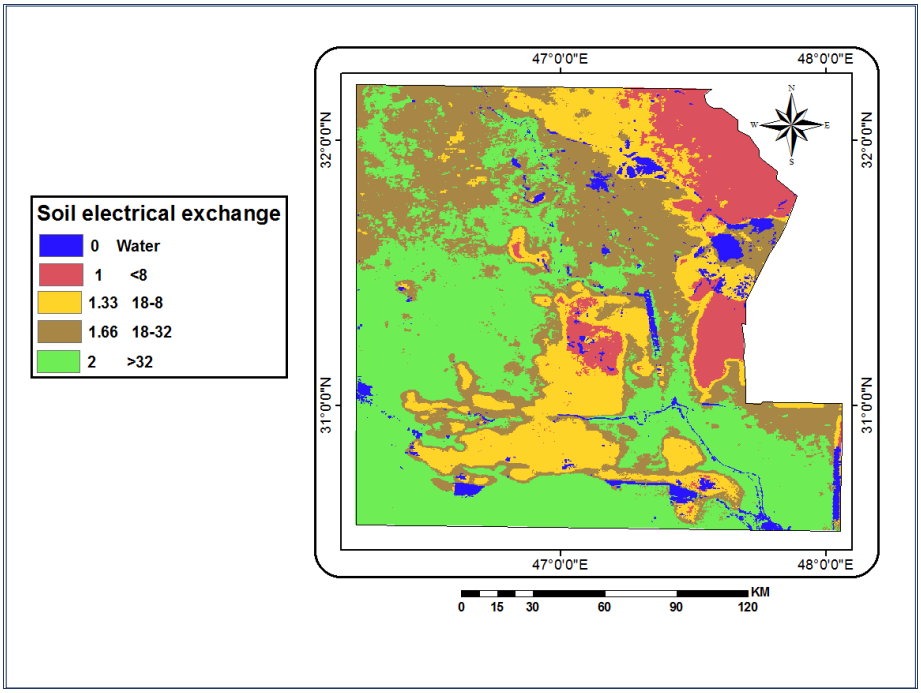


Fig. 9. Soil electrical exchange classes and scores of the southern Iraqi Marshland.

3.1.8. Soil pH

The soil alkalinity data of the study area is presented in Table 10 and Fig. 10. As the alkalinity increases, the Soil becomes more susceptible to desertification. The areas that include an area of 371.94 km^2, about 1.33% of the study area, have little alkalinity and are less prone to desertification sensitivity, as it was given a value of 1.00 on the desertification scale. The moderately alkaline areas include an area of 609.51 km^{2,} with about 2.18% of the study area giving a value of 1.33 on the scale of desertification sensitivity. While the areas with high alkalinity, covering an area of 26012.21 km^2 with about 92.94% of the study area, were given a value of 2.00 on the scale of desertification sensitivity and are more susceptible to desertification than the rest of the areas.

Table 10. Distribution of Soil pH classes and assigned scores in the study area.

Type	Score	Area Km^2	Area %	Class
Water bodies	0	995.34	3.56	
0.1 - 7.2	1	371.94	1.33	Slightly alkaline
7.3 - 7.5	1.33	609.51	2.18	Moderately alkaline
7.6 - 8.1	2	26012.21	92.94	Very strongly alkaline
Total		27989	100	

3.2. Soil Quality Index map

The sensitivity map of desertification was calculated using the SIQ, as shown in Tables 11 and Fig. 11. Compared to the quality categories in the MEDALUS model, the results found that the Soil in the study area is divided into two categories. Class 1 (high sensitive) with an area of 984 km^2, which occupies about 3.52% of the study area, and Class 2 (low sensitive) with an area of 27,005 km^2, which occupies 96.48% of the study area. The decline in soil quality is due to many factors related to soil properties. It constitutes 61% of the Soil Parent is of low quality, and the depth of the Soil is about 70% with a shallow depth between 15 and 30 cm this depth reduces the soil's water retention, and the creation of fragments is few, about 40% of the area is few to barren, and this increases the process of erosion.

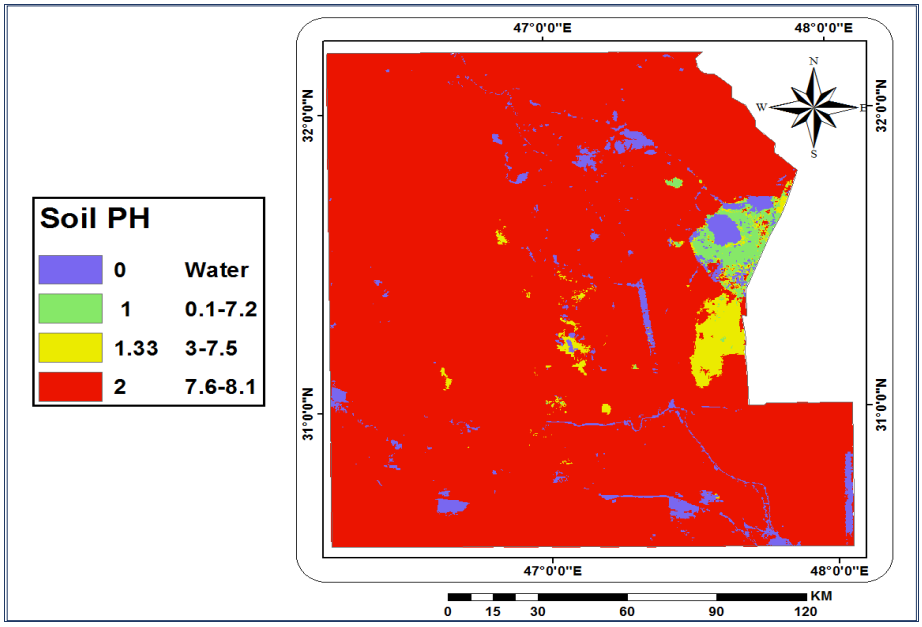


Fig. 10. Soil pH classes and scores of the southern Iraqi Marshland

Table 11. Soil Quality Index of the southern Iraqi Marshland.

Type	Score	Area Km^2	Area %	Class
1	<1.13	984	3.52	Low sensitive
2	>1.46	27005	96.48	High sensitive
Total		27989	100	

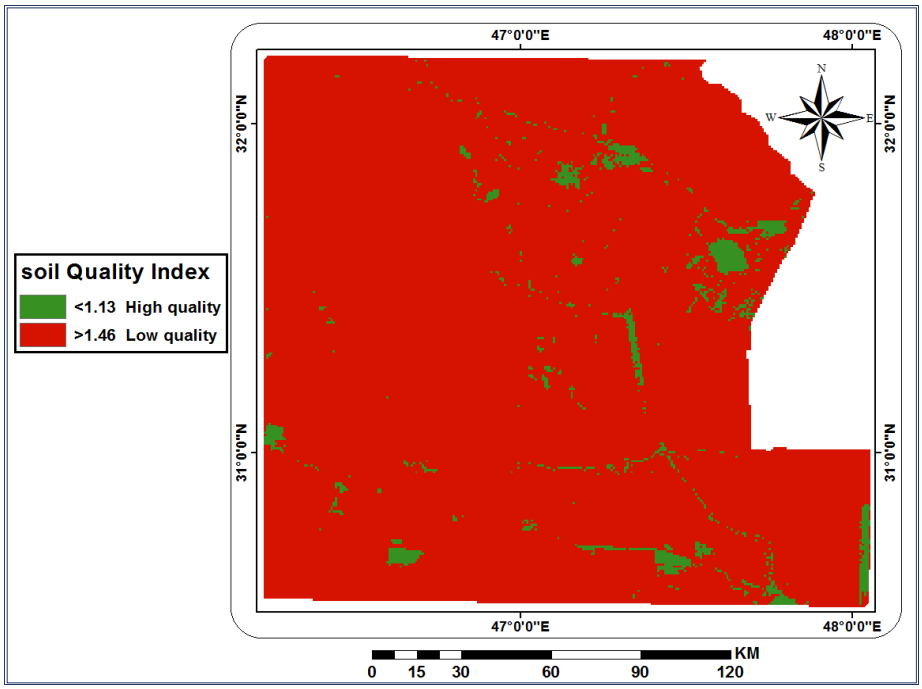


Fig. 11. Soil quality index of the southern Iraqi Marshland

The organic carbon in the Soil was significantly low, as 80% of the Soil is very poor, and this reduces the Soil's water retention and increases the process of surface water runoff. The electrical exchange of the Soil is weak, and 40% of the area is low reactive, which reduces the ion exchange

between the Soil and plants, and thus the plant decreases. The Soil is prone to erosion, and the Soil of the area is high in pH as 92% of the area is very alkaline. These factors make the Soil susceptible to desertification.

4. Conclusions

The current study produced the sensitive desertification map from the SQI using the most important soil factors. Remote sensing was used as a source of data, and the GIS program as an analysis processing tool that allows map creation and analysis regularly to be used for special purposes. The study found that the soil of the marshes is divided into two categories, the first represents about 3.52% with an area of about 984 $km^{2,}$ and it was not sensitive to desertification. In contrast, the second category represents about 96.48% with an area of 27,005 km^2 and is sensitive to desertification according to eight parameters related to soil properties. Most areas of study constitutes the soil parent of low quality. The soil depth of the study area between 15 and 30 cm represented shallow depth which increases the process of erosion. The lower organic carbon led to increase in the runoff process. The electrical exchange value of the study area is low, with less ion exchange between the soil and plants. The soil is prone to erosion and the soil of the area is high pH as 92% of the area is very acidic. These factors make the soil susceptible to drying and sensitive to desertification.

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