USING THE ENVIRONMENTAL SENSITIVITY SCENARIOS OF DESERTIFICATION IN ARID AND SEMI-ARID REGIONS (A CASE STUDY OF THE AL-NASR AREA IN DHI QAR, IRAQ.)

Raad A. Abbood[1] A.A Jafarzadeh[2] A. I. Hamad[3] Shahin Oustan[2]
Researcher Prof. Prof. Prof.
[1]Scientific Research Commission, Baghdad, Iraq.
[2]Dept. Soil sci. Facu. Agri. University Tabriz, Tabriz, Iran.
[3]Dept. Deser. Com. Coll. Agri Engin Sci /University of Baghdad, Iraq
raad.a.bbood@src.edu.iq, ajafarzadeh@tabrizu.ac.ir, oustan@tabrizu.ac.ir

ABSTRACT

This study aimed to assess desertification and land degradation in an arid and semi-arid climate (Al-Nasr area, Dhi Qar Governorate). We used the MEDALUS and modified MEDALUS models with three scenarios, in conjunction with GIS mapping techniques, to identify desertification risks in one Iraqi governorate. After creating a desertification database containing 19 criteria, the first steps consisted of mapping four MEDALUS indicators, including soil, vegetation, climate, and land management. The next step involved adding other indicators such as irrigation water. All layers weighted by environmental conditions present in the region were then used according to the same MEDALUS framework to create a desertification map. The results showed that the modified MEDALUS models DSI2 and DSI3 performed better, with the unaffected type covering 44,623.6 and 48,817.2 hectares, representing 47% and 51% of the study area, while the severely affected type covered 41,971.7 and 35,490.8 hectares, representing 44% and 37% of the study area, respectively. For the DSI1 model, the unaffected type covered 28,968.6 hectares, representing 30.5%, while the affected type covered a very small area of the study area.

Keywords: irrigation, water quality, management quality, land degradation.

استخدام سيناريوهات في نموذج الحساسية البيئية للتصحر في المناطق القاحلة وشبه القاحلة (دراسة حالة منطقة النصر في ذي قار، العراق)

رعد عبدالكاظم عبود علي اصغر جعفرزادة عبدالغفور إبراهيم حمد شاهين اوستان
باحث أستاذ أستاذ أستاذ
[1]هيئة البحث العلمي، بغداد، العراق.
[2]قسم علوم التربة – كلية الزراعة – جامعة تبريز-إيران
[3]قسم التصحر – كلية علوم الهندسة الزراعية – جامعة بغداد – العراق

المستخلص

هدفت هذه الدراسة إلى تقييم التصحر وتدهور الأراضي في مناخ جاف وشبه جاف (منطقة النصر، محافظة ذي قار). استخدمنا نموذجي MEDALUS وMEDALUS المُعدَّل بثلاثة سيناريوهات، بالتزامن مع تقنيات رسم خرائط نظم المعلومات الجغرافية، لتحديد مخاطر التصحر في إحدى المحافظات العراقية. بعد إنشاء قاعدة بيانات للتصحر تتضمن 19 معيارًا، شملت الخطوات الأولى رسم خرائط لأربعة مؤشرات MEDALUS، بما في ذلك التربة والغطاء النباتي والمناخ وإدارة الأراضي. تضمنت الخطوة التالية إضافة مؤشرات أخرى مثل مياه الري. ثم استُخدمت جميع الطبقات الموزونة بالظروف البيئية السائدة في المنطقة وفقًا لإطار MEDALUS نفسه لإنشاء خريطة للتصحر. أظهرت النتائج أن نموذجي MEDALUS المُعدَّلين DSI2 وDSI3 كانا أفضل أداءً حيث كانت مساحة الصنف الغير متأثر 44623.6 و48817.2 هكتار وبنسبة 47% و51% اما الصنف المتأثر الشديد فقد كان 41971.7 و35490.8 هكتار بنسبة 44% و37% من منطقة الدراسة على التوالي، اما نموذج DSI1 فقد شكل الصنف الغير متأثر مساحة 28968.6 هكتار بنسبة 30.5% والصنف المتأثر بمساحة قليلة جدا من منطقة الدراسة.

الكلمات المفتاحية: جودة مياه الري، جودة الإدارة، تدهور الأراضي.

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Received: 27/11/2024, Accepted:12/2/2025, Published: August,2025

INTRODUCTION

Land degradation and subsequent desertification have increased dramatically worldwide since the middle of the last century and pose a serious threat to countries in arid, semi-arid, and even humid regions. This is driven by rising average temperatures and declining annual rainfall, which has fallen to less than 100 mm in over 72 percent of Iraq's area, affecting 69 percent of its agricultural land (10, 17, 28, 31, 41).Land degradation and desertification encompass processes caused by natural factors and human mismanagement (6, 35). Desertification has several definitions, all from the point of view of specialists. Agriculturalists have defined it as the land becoming zero in agricultural productivity and therefore deteriorating (17, 18, 19). From an environmental perspective, desertification is an environmental change that results in a new dry and barren environment, or it is the process of land degradation in arid, semi-arid, dry and sub-humid areas due to various factors, including human activities and climate change (1, 2, 3, 7, 16). There are many factors such as deforestation, drought, overgrazing, climate change, soil pollution, unplanned agriculture, etc. that accelerate or slow down the process of desertification (5, 6, 10). Desertification, land degradation, and drought are issues that pose serious challenges to the sustainable development of all countries and cause many problems, including land resource scarcity, poverty, reduced food resources, and reduced global agricultural production and economic development (7, 14, 29, 39). The final results, evaluated using the proposed Desertification Sensitivity Index (DSI) using the MEDALUS method (based on 14 sub-indices), showed that approximately 82% of the total study areas were highly sensitive to desertification, mainly due to the drought index, rainfall, fire risk, and land use in California counties (5, 11, 12, 13, 21, 33, 34, 35). While the area exposed to very high sensitivity to desertification is about 94.97% (949.7 hectares) of the study area and the area suffers from sensitivity to desertification due to poor management, topographical conditions, scarcity of vegetation cover, poor land exploitation, soil quality, wind erosion, in addition to climatic conditions(22, 32). The southern area of Iraq is considered more vulnerable to desertification (22). Supervised classification was used on satellite images of the Nasr area to reveal dune expansion and land degradation, with the dune area expanding from Approximately 8,000 hectares to 18,000 hectares over a ten-year period (1). In the Sidi Abdel Rahman region of Egypt, the MEDALUS model detected approximately 79.37% of the study area as sensitive and affected by desertification due to low vegetation cover, soil quality, poor management, climatic conditions, and wind and water erosion (11). The physical and chemical soil properties are spatial variability such as particle size, bulk density, Electric conductivity, organic matter, Minerals as well as the chemical degradation of soil (24, 36). Based on the results of the modified MEDALUS model, approximately 23.5% of the total area was classified as high risk of desertification, and 76.5% as very high risk of desertification (6). The results indicate that climate, vegetation cover, and groundwater quality are the most important factors driving desertification in the study area (4, 15). Erosion indicators (wind and water) and soil are of secondary importance (6, 42, 44). The objectives are as follows:

1- The main objective of this study is to assess desertification in arid and semi-arid regions and monitor the evolution of desertification in this environment.

2- Preparing desertification maps based on the MEDALUS model for the study area using remote sensing and (GIS) techniques.

MATERIALS AND METHODS

Location of the study area: The study area consists of Tigris River sediments, marshes and swamps, which are part of the alluvial plain. It represents the southern part of Al-Rifai District, located in the northern part of Dhi Qar Governorate, southern Iraq. Its area is estimated at 95,000 hectares, equivalent to about 14% of the total area of Dhi Qar Governorate (1), which amounts to 13,839 square kilometers. Al-Muthanna Governorate borders it to the west, while it is bordered to the south by Al-Nasiriyah District and to the east by Al-Shatrah District. The area extends between longitudes 46° 16' 53" east and 45° 44' 57.427" east, and latitudes 31° 39' 7.55" north and 31° 17' 51.689" north, as shown in Figure 2.

Field and office work

Soil survey and determination of the study area: Among the 37 major global challenges, it is among the three major challenges facing humanity in the 21st century, after climate change and freshwater scarcity, which reduce the potential of land and destroy renewable resources. Hence, the importance of recognizing and appreciating this phenomenon. This research will be conducted in the Al-Nasr area in Dhi Qar Governorate, located in southern Iraq with an area of 95,919. hectares and a geographical location between 45°43'00" and 46°20'00" east longitudes and 00°20'31" and 00°35'31" north latitudes. The study areas are characterized by uniform terrain, so to study the risks of land degradation and desertification, the results of laboratory soil analysis of 90 surface soil samples from a depth of 25 cm will be used. Since the most important factors affecting the risk of desertification in these areas are climate change and land use, the risk of desertification will be estimated through the MEDALUS model using four to five Criteria (4, 30, 37). In addition, since remote sensing technology based on providing spatial information (at specific time intervals) plays a very valuable role in assessing and monitoring desertification at various local, regional and global scales (25). This research uses data from Landsat 8 satellite images in the year (2024) with a spatial resolution of 30 x 30 square meters in OLI received from the USGS website.

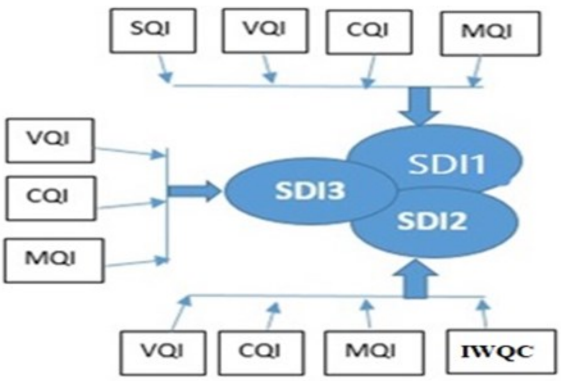

Figure 1. Research Study research outline

Inputs for Desertification Assessment in the Study Area the MEDALUS Model.

The MEDALUS project was first implemented over a period of nine years and in three phases, from 1991 to 1999 (38), and is currently used to assess desertification in most countries bordering the Mediterranean and the Middle East. This model identifies the factors influencing desertification in the region, and each criterion is taken into account (4, 8, 9). The characteristics of the criteria listed below, which are considered effective in combating desertification in the region, are then considered indicators. Each indicator is classified into five categories based on its sensitivity to desertification: very low (1.6–2.0), low (1.45–1.6), medium (1.3–1.45), high (1.15–1.3), and very high (1–1.15) (21). This method identifies areas environmentally sensitive to desertification using the geometric mean of four criteria, including environmental and human impacts. These standards include Soil Quality Criteria (SQC), Climate Quality Criteria (CQC), Vegetation Quality Criteria (VQC), and management quality criteria and human impact (MQC), Irrigation water quality criteria (IWQC) (Figure 3). The score for each criterion is determined and ranked by calculating the geometric mean (Equation 1) of the scores of the associated indicators:

XQC = (s1 × s2 ×…× sn)1/n……………..(1)

Where XQC is the score for each criterion, s (1, 2, n, ...,) is the score for each indicator, and n is the number of indicators. Finally, the Environmentally Sensitive Areas to Desertification Index (ESAI) is obtained by calculating the geometric mean of the scores for the selected criteria (Equation 2):

ESAI = (SQC × CQC × VQC × MQC) ¼...(2)

Desertification assessment according to the MEDALUS model and the Modified MEDALUS model: Where SQC is the soil quality criterion, VQC is the vegetation quality criterion, CQC is the climate quality criterion, MQC is the management and human impact quality criterion, and IWQC is the Irrigation Water Quality Criterion. The ESAI index is classified into eight categories, as shown in the table 1.Finally, the Environmentally Sensitive Areas to Desertification (ESA) maps are presented as follows: They were obtained using the invers distance weighted (IDW) interpolation technique. This technique produces values for unknown points from a weighted sum of values (17). Known points it is explains that the criteria and indicators for each criterion are chosen according to local characteristics and field observations (23).

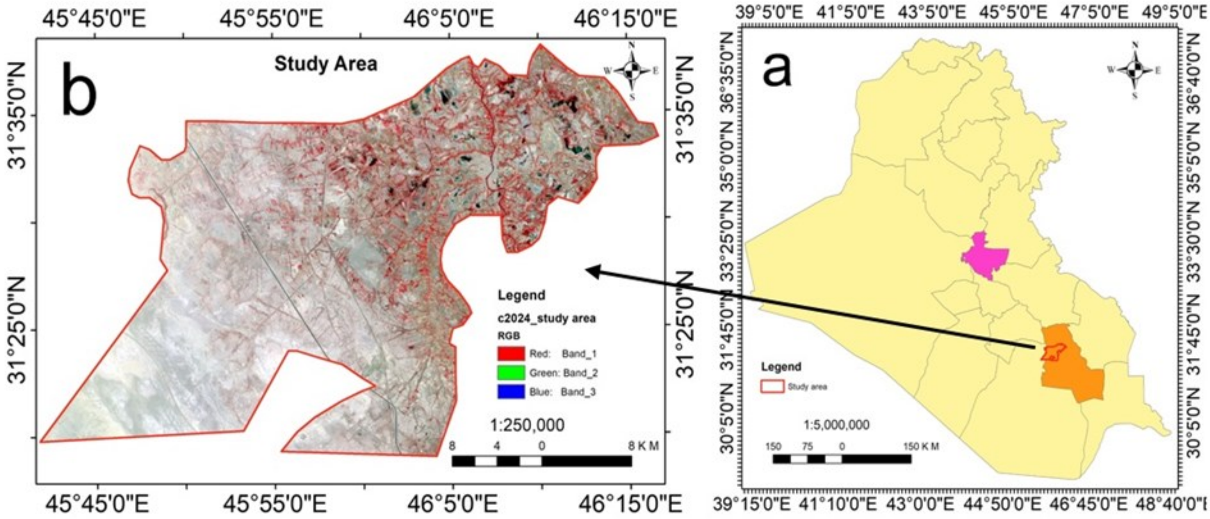

Figure 2. Map of (a) Iraq showing Dhi Qar province, and (b) a satellite image of Al-Nasr District

Criteria used in desertification potential assessment models:

Soil Quality Criteria (SQC): This index is calculated based on the results of six indicators: soil lime ($CaCO_3$), soil electrical conductivity (EC), soil gypsum (GYP), soil organic matter (OM), sodium absorption ratio (SAR), and soil texture (Tex) and is based on the physical and chemical properties of soil which represent spatial variation such as particle size, bulk density, electrical conductivity, organic matter and minerals. (22, 40), (Equation 3).

$SQC = (Ece*OM*SAR*Tex*GYP*CaCO_3)^{1/6}$…(3)

Vegetation Quality Criteria (VQC)

In this study, vegetation quality will be assessed using scores for three indicators: drought resistance (DR), fire risk (FR) Most of the fire risk comes from vandals in the study area, who occasionally set fire to forests created by the sand dune stabilization project to extract charcoal and sell it on the market. This negatively affects the study area in terms of land degradation and desertification, as shown figure (3). In addition, vegetation cover (C). The DR and FR indicators are extracted from the land use map, the vegetation index is extracted from the normalized difference vegetation index (NDVI), and the VQC is calculated from the following equation 4 (43):

$V= QC = (DR \times FR \times C \times PE)^{1/4}$……..(4)

Climate Quality Criteria (CQC): The climate quality criteria are calculated based on two indices: precipitation (R) and aridity index (AI), based on the climatic indices presented by (27) and their corresponding scores. The precipitation and potential evapotranspiration indices were obtained from six monitoring stations located in the study area, and the aridity index was calculated from the ratio of annual precipitation to potential evapotranspiration. The climate quality index (CQC) is calculated according to the following formula:

$CQC = (R \times AI)^{1/3}$…...(5)

Table 1. Types of ESAs and corresponding ranges of indices (26)

Class	Description	Range of ESAI
NA	**Non affected**	**<1.17**
P	**Potential**	**1.17 – 1.22**
F1	**Fragile1**	**1.23 – 1.26**
F2	**Fragile2**	**1.27- 1.32**
F3	**Fragile3**	**1.33 – 1.37**
C1	**Critical1**	**1.38 -1.41**
C2	**Critical2**	**1.42 – 1.53**
C3	**Critical3**	**>1.53**

Management Quality Criteria (MQC): The Management Quality Criteria is calculated based on grazing intensity (G), population density (PD), and conservation practices (CP) using the following formula:

$MQC = (G \times PD \times CP)^{1/3}$…(6)

Irrigation Water Quality Criterion(IWQC): The quality of irrigation water depends on four indicators: salinity of irrigation water Ec, chlorine content Cl, sodium content SAR and heavy elements content TDS, and iscalculated according to the following equation:

IWQC = (Ec × Cl × SAR × TDS)¼……..7

Table 2. Soil Quality Criteria (SQC)

Index	Class	Description	Ec	Weight
Ec	1	Very low	<4	1
	2	Low	4-8	15
	3	Moderate	8-16	1.8
	4	High	>16	2
Texture	1	Good	L, SCL, SL, LS,CL	1
	2	Moderate	SC,SiL,SiCL	1.3
	3	poor	Si, C, SiC	1.6
	4	Very poor	S	2
SAR	1	Very low	<3	1
	2	Low	3.0-6.0	1.3
	3	Moderate	6.0-13.0	1.6
	4	High	>13	2
Gypsum	1	good	<10	1
	2	accepted	10.0 – 20	1.2
	3	Moderate	20 -30	1.5
	4	High	30 - 40	1.8
	5	Very High	>40	2
CaCO3	1	good	<15	1
	2	accepted	15-20	1.2
	3	Moderate	20-25	1.6
	4	High	>25	2
O.M	1	Good	>3	1
	2	Moderate	2.0 – 3.0	1.2
	3	poor	1.0 - 2.0	1.5
	4	Very poor	<1	2

RESULTS AND DISCUSSION

The difference in Soil quality index categories is due to the different weighted index values of studied soil properties. The reason for the high or low Soil quality index values is due to the high values of gypsum, which negatively affects the weighted index values for soil quality. Meanwhile, the calcium carbonate index, soil texture, and SAR values were good for most of the study sites. As for organic matter, the weighted index was distributed in most sites as good to average, with approximately 15% of the study area having low quality. This was also reflected in the soil salinity index, with a slight change in the weighted index percentage, reaching 5% of the study area having low quality. These indicators ultimately indicate that 80% of the study area has high soil quality, 15% has medium soil quality, and 5% has low soil quality (Table 8, Figure 4).

Figure 3. Fire risk, date of shooting (3-5-2025)

The Climate Quality Criteria (CQC)

The Climate Quality Criteria (CQC) was evaluated based on two main indicators: the aridity index and the rainfall index. The aridity index was estimated based on the ratio of annual rainfall to evapotranspiration (45). The study area was divided into two zones according to the weighted index: 60% good and 40% low quality. Regarding the rainfall index, the study area receives less than 280 mm of annual rainfall, so it was classified as an arid climate, which represents the third low category. The weighted index was taken as 2. Based on the previous two indicators, the CQC value was found to be 40% good, 30% average, and the weighted index was taken as two. Based on the previous two indicators, the CQC value was found to be 40% good, 30% average, and 30% low for all samples in the study area table 8 Fig. (4).

Vegetation Quality Index (VQI)

Vegetation quality indices were calculated based on three indices: the vegetation index, the aridity index, and the fire danger index. The vegetation index was calculated based on the National Normalized Difference Vegetation Index (NDVI) values to calculate the percentage of natural vegetation cover. The aridity index was calculated based on the Lange Aridity Index (Rainfall Index), which is calculated as the ratio of total annual rainfall to average annual temperature. The fire danger index represented 96% of good quality. Therefore, the results of the vegetation quality index values ranged into three categories: the first category, which falls within the range of less than 1.33, represents good quality, equivalent to 30%, and represents one-third of the total area of the study area. The second category, which falls within the range of 0.9 to 1.66, represents medium quality, equivalent to 10% of the study area. The third category, which falls within the range of more than 1.66, represents poor quality, equivalent to 60%, as shown in Table (8) and Figures 4.

Management Quality Criteria (MQC)

The Management Quality Criteria (MQC) was based on three indicators: grazing intensity, conservation practices, and population pressure. The first indicator, grazing intensity, was divided into three categories: low, medium, and high, with percentages of (30, 25, and 45%), respectively, and weighted indexes of (1, 1.5, and 2). As for management policy practices, the study area was under incomplete protection and was therefore classified into three categories: low, medium, and high, with percentages of (50, 25, and 30%), respectively, with weighted indexes of (1, 1.5, and 2). The third indicator, population pressure, was classified into three categories: high, medium, and low, with percentages of (50, 15, and 35%), respectively, with weighted indexes of (2, 1.5, and 1). Based on the previous indicators, management quality standards were classified into three categories: with percentages of good 35%, medium 60%, and low quality 5%, for all samples in the study area, as shown in Figures 4 and Table (8).

Irrigation Water Quality Criteria (IWQC)

Irrigation Water Quality Control (IWQC) criteria were based on four irrigation water parameters (chloride content, irrigation water salinity, SIR, and heavy metals in irrigation water). The chloride content in irrigation water represented the highest weighted value for most of the study area, in contrast to the SIR, which showed the lowest value for most of the study area. The irrigation water salinity represented 25% as a weighted good value, 15% as average, and 60% as low. Heavy metals in irrigation water represented 30% as good, 15% as average, and 55% as low for the total study area. This, in turn, provided us with a map of irrigation water quality for the study area, showing that 30% was good, 20% as average, and 50% as low Table 8, Figures 4.

Table 3. Vegetation Quality Criteria (VQC)

Fire Risk	Class	Description	Type of Vegetation	Weight
	1	Low	Bare land	1
	2	Moderate	Annual agricultural crops, Grasslands	1.5
	3	High	Dense and open forest(existence of shrubs, shrubs, tree layers)	2
Drought Resistance	**Class**	**Description**	**Type of Vegetation**	**Weight**
	1	High	Dense and open forest(existence of shrubs, shrubs, tree layers)	1
	2	Moderate	Permanent grasslands	1.3
	3	Low	Annual agricultural	1.6
	4	Very low	Bare land	2
Plant Caver	**Class**	**Description**	**Plant Caver %**	**Weight**
	1	High	>33%	1
	2	Low	10 – 35%	1.5
	3	Very low	<10%	2

Table 4. Climate Quality Criteria (CQC)

Rainfall	Class	Description	Rainfall (mm)	Weight
	1	High	300	1
	2	Moderate	150 - 300	1.5
	3	Low	150	2
Evapo-transpiration	**Class**	**Description**	**Evapo-transpiration**	**Weight**
	1	High	1500	1
	2	Moderate	1500 - 2000	1.5
	3	Low	2000	2
Aridity	**Class**	**Description**	**Aridity index (P/Etp)**	**Weight**
	1	High	Al ≥ 1	1
	2	Moderate	0.1< Al <1	1.5
	3	Low	Al ≤0.1	2

Table 5. Management Quality Criteria (MQC)

Grazing Intensity	Class	Description	Animal Small Unit	Weight
	1	Low	1	1
	2	Moderate	1 – 2.5	1.5
	3	High	>2.5	2
Population Pressure	Class	Description	Population Pressure	Weight
	1	Low	<0.5	1
	2	Moderate	0.5 – 1	1.3
	3	High	1 – 1.5	1.6
	4	Very High	>1.5	2
Conservation Practices	Class	Description	Plant Caver %	Weight
	1	High	Al ≥ 1	1
	2	Moderate	0.1< Al <1	1.5
	3	Low	Al ≤0.1	2

Environmental Sensitivity Index

The Environmental Sensitivity Index (ESAI) was based on five criteria: (Soil Quality Index, Climate Quality Index, Vegetation Quality Index, Management Practices Index, and Irrigation Water Quality Index) (22, 39, 41). By applying three scenarios to this equation, the Environmental Sensitivity Index (ESAI) equation, based on the above indicators, was developed. The first scenario used four indicators in the equation above: (Soil Quality Index, Climate Quality Index, Vegetation Quality Index, and Management Practices Index). The first desertification sensitivity map was produced, and seven environmental sensitivity categories were obtained, as shown in Table 8. We note the presence of categories (Non affected, Potential, Fragile, and Critical), which are divided into categories (N, P, F1, F2, C1, C2, and C3), (22) as shown in Table (8) and Figure (4). Class N, represented by the unaffected class, occupied an area of 28,968.6 hectares, equivalent to 30.5% of the study area, representing one-third of the study area not affected by desertification sensitivity. The tolerant class, represented by class B, occupied an area of 32,875.7 hectares, equivalent to 34.6% of the study area, and represents areas at risk of desertification in the event of poor management and high temperatures, which consequently increase evaporation and decrease rainfall, and the subsequent deterioration. The fragile class, found under the Fragile 1 and Fragile 2 classes, covered an area of 17,513.6 and 11,497.6 hectares, equivalent to 18.4% and 12.1%, respectively, of the total area The critical category occupies the smallest areas in the study area, namely Critical 1, Critical 2, and Critical 3, with areas of 3289.1, 864.6, and 309.2 hectares, representing percentages of 0.03%, 0.009%, and 0.003% of the study area, respectively.

Table 6. Irrigation Water Quality Criterion (IWQC) and weight

Index	Class	Description	Criteria	Weight
Ece	1	High	< 0.7	1
	2	Moderate	0.7 - 3	1.5
	3	Low	>3	2
Cl	1	High	4	1
	2	Moderate	4-10	1.5
	3	Low	<10	2
SAR	1	Very high	3	1
	2	High	3-6	1.2
	3	Moderate	6-12	1.5
	4	Low	12-20	1.7
	5	Very low	20-60	2
TDS	1	Low	<450	1.4
	2	Moderate	450 – 2000	1.8
	3	High	>2000	2

Table 7. Percentage of all criteria used in the model (20)

Index	Description	Class	Range	Percentage
SQC	High quality	1	< 1.33	80%
	Moderate	2	1.34 – 1.166	15%
	Low	3	>1.66	5%
CQC	High quality	1	< 1.33	40%
	Moderate	2	1.34 – 1.166	30%
	Low	3	>1.66	30%
VQC	High quality	1	< 1.33	30%
	Moderate	2	1.34 – 1.166	10%
	Low	3	>1.66	60%
MQC	High quality	1	< 1.33	35%
	Moderate	2	1.34 – 1.166	60%
	Low	3	>1.66	5%
IWQC	High quality	1	< 1.33	35%
	Moderate	2	1.34 – 1.166	60%
	Low	3	>1.66	5%

The second scenario used four indicators in the equation above (9): the climate quality index, the vegetation quality index, the management practices index, and the Irrigation water quality index. This produced the second desertification sensitivity map, and six environmental sensitivity categories were obtained, as shown in Table (8). We note the presence of categories (unaffected, tolerant, fragile, and critical), which are divided into categories (N, P, F1, F2, C1, C2), as shown in Table (8) and Figure (4). Class N, represented by the unaffected class, occupied an area of 44,623.6 hectares, equivalent to 47% of the study area, representing half of the study area not affected by desertification sensitivity. The tolerant class, represented by class P, occupied an area of 2,293.0 hectares, equivalent to 0.024% of the study area, which is a very small area, and represents areas at risk of desertification in the event of mismanagement and high temperatures, which consequently increases evaporation and decreases rainfall, and the subsequent deterioration (23). The fragile class, found under the Fragile 1 and Fragile 2 classes, occupied an area of 1,573.7 and 2,065.4 hectares, equivalent to 0.016% and 0.021%, respectively, of the total area (23). The critical category occupies slightly less than half of the study area, with Critical 1 and Critical 2, covering 2,455.2 and 41,971.7 hectares, representing 0.025% and 44% of the study area, respectively (4). Finally, the third scenario used three indicators in the equation above: the Climate Quality Index, the Vegetation Quality Index, and the Management Practices Index. This produced the third desertification sensitivity map, and seven environmental sensitivity categories were obtained, as shown in Table (8). We note the presence of categories (Non affected, Potential, fragile, and critical), which are divided into categories (N, P, F1, F2, C1, C2, C3) (13, 14, 17), as shown in Table (8) and Figure (4). Class N, represented by the unaffected class, occupied an area of 48,817.2 hectares, equivalent to 51% of the study area, representing more than half of the study area not affected by desertification sensitivity. The tolerant class, represented by class B, occupied an area of 1,673.0 hectares, equivalent to 0.02% of the study area. This is a very small area, and represents areas at risk of desertification in the event of mismanagement and high temperatures, which consequently increase evaporation and decrease rainfall, and the subsequent deterioration. The fragile variety was found under the fragile 1 and fragile 2 varieties, and the critical variety was found under the category in three categories: critical 1 and critical 2, with very small areas of 1437.0, 2550.0, 3169.0, and 2154.0 hectares, equivalent to 0.015%, 0.026%, 0.033%, and 0.022% of the total area, respectively. As for the critical variety 3, it occupies more than a third of the region with an area of 35490.8 hectares, representing 0.37% of the study area (20).

CONCLUSION

The results showed that the Modified MODALUS model (DSI2, DSI3) is closer to reality, as it showed the fragile and critical areas in large areas of the total area of the study area. According to the map of the study area, Figure 2, these sites are the areas expected to be critical and fragile for several reasons, including their distance from fresh water sources. The Gharraf River, their distance from residential areas and transportation routes, their being characterized by sand dune lands, their distance from transportation routes and their distance from services, and they are almost devoid of any vegetation due to their proximity to the Great Desert in the western part of Iraq, Figure 3. As for the MODALUS model, it showed the exact opposite, as it showed that the unaffected areas are located within the desert climate, and the fragile and critical areas are located near water sources and are characterized by good vegetation cover, as in the vegetation quality map. This is due to the effect of the soil quality map on this result, as when it was excluded from the second and third Models; it gave results close to reality.

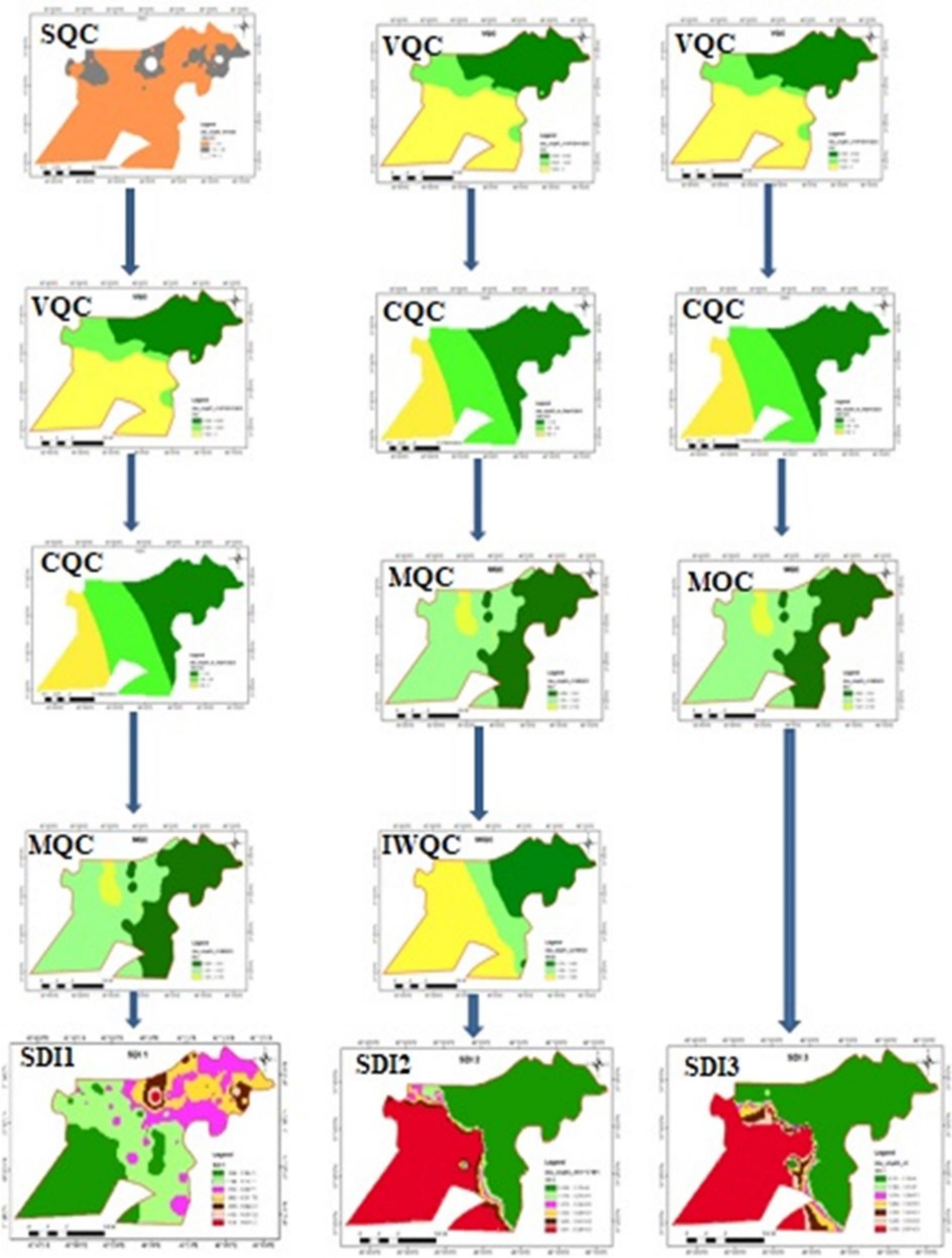

Figure 4. These maps represent the SDI1 map, the SDI2 map, the SDI3 map

RECOMMENDATION

The Modified MODALUS model has been widely used in numerous international studies due to its ease of application and suitability for various environments, particularly arid and semi-arid regions. Therefore, we recommend its widespread application in Iraq, given its positive results. We also recommend the addition of an Irrigation water quality index, given its proven results on the ground. We recommend using the fire hazard index to assess the area's exposure to arson fires for the purpose of financially benefiting from the coal produced by the fires, given its significant role in land degradation figure(3).

Table 8. Environmental sensitivity index to desertification of the soils of the study area

No.	Class	ESAI	DSI1 Area_ ha	%	DSI2 Area_ ha	%	DSI3 Area_ ha	%
1	N	<1.17	28968.6	30.5%	44623.6	47%	48817.2	51%
2	P	1.17 – 1.22	32875.7	34.6	2293.0	0.024%	1673.0	0.02%
3	F1	1.23 – 126	17513.6	18.4	1573.7	0.016%	1437.0	0.015%
4	F2	1.27 – 1.32	11497.6	12.1	2065.4	0.021%	2550.0	0.026%
5	C1	1.38 – 1.41	3289.1	0.03	2455.2	0.025%	3169.0	0.033%
6	C2	1.42 – 1.53	864.6	0.009	41971.7	44%	2154.0	0.022%
7	C3	>1.53	309.2	0.003	--------	------	35490.8	37%

Acknowledgments

This study was conducted in the Department of Soil and Water Resources, Faculty of Agriculture, University of Tabriz, as part of a doctoral dissertation project titled "Predicting Regional Changes in Land Degradation and Desertification Risks Using Different Models in Dhi Qar Province, Iraq." The researchers would like to thank the Director of the Sand Dune Stabilization Project, Mr. Qahtan Al-Muhanna, for his assistance in fieldwork in the study area, and Dr. Hatem Al-Ghazi, Director General of the Agricultural Research Department, and Dr. Fadhel Al-Husseini, and Chief Agricultural Engineer Abdul Rahman from the Ministry of Agriculture for providing climate data for the study area and conducting laboratory experiments. We also extend our sincere thanks to Dr. Sadiq Jaafar, Head of the Soil Department of the Scientific Research Commission, for conducting laboratory experiments in his laboratories. We also thank Dr. Alaa G. Khalaf, a researcher at the Space Research and Technology Center, Scientific Research Commission, for providing us with topographic maps of the study area and for his support in this research.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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