ASSESSMENT OF THE ENVIRONMENTAL SENSITIVITY OF DESERTIFICATION IN SOUTHERN IRAQ, AL-SAMAWA BADIA USING GIS AND RS TECHNIQUES

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ABSTRACT

This study was aimed to investigate and evaluates the degree of environmental sensitivity of desertification and to provide solutions, treatments by identifying the elements and indicators that are directly linked to desertification in southern Iraq. GIS technique was used, and mapping of environmentally sensitive areas for desertification. Five important indices including (soil quality index SQI, climate quality index CQI, vegetation quality index VQI, management quality index MQI, and groundwater quality index GWQI) were used. Results showed that the SQI index was varied between high, moderate, and low quality, the VQI index was varied between moderate to low quality, as for the indices of (CQI, MQI, and GWQI), all classifications were within the lower class. This was reflected negatively on the values of environmental sensitivity to desertification (ESAI) and it became in the critical category within the study area. Consequently, the environmental sensitivity to desertification was calculated by excluding the indices of MQI, and GWQI. Four classes were detected (None affected, Potential, Fragile, and Critical) divided into sub-classes (N, P, F3, C1, C3).

Keywords: Soil quality index, climate quality index, vegetation quality index.

تقييم الحساسية البيئية للتصحر في جنوب العراق، بادية السماوة بإستعمال تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد

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المستخلص

هدفت هذه الدراسة الى معرفة وتقييم درجة الحساسية البيئية للتصحر وتقديم الحلول والمعالجات من خلال تحديد العناصر والمؤشرات المرتبطة مباشرة بالتصحر في جنوب العراق. تم استخدام تقنية نظم المعلومات الجغرافية ورسم خرائط للمناطق الحساسة بيئياً للتصحر, إذ أستخدم خمسة مؤشرات مهمة تشمل (مؤشر جودة التربة SQI ، مؤشر جودة المناخ CQI ، مؤشر جودة الغطاء النباتي VQI ، مؤشر جودة الإدارة MQI ، ومؤشر جودة المياه الجوفية GWQI), أوضحت النتائج أن مؤشر SQI كان متفاوتاً بين جودة عالية ومتوسطة ومنخفضة ، وتفاوت مؤشر VQI بين جودة متوسطة إلى منخفضة ، أما بالنسبة لمؤشرات (CQI و MQI و GWQI) ، فجميع التصنيفات كانت ضمن الفئة الأدنى, وقد انعكس ذلك سلباً على قيم الحساسية البيئية للتصحر (ESAI) وأصبحت في الفئة الحرجة داخل منطقة الدراسة, وبالتالي تم حساب الحساسية البيئية للتصحر بأستبعاد مؤشرات MQI و GWQI. حيث تم الكشف عن أربع فئات (غير متأثرة ، محتملة ، هشة وحرجة) مقسمة إلى فئات فرعية (N، P، F3، C1، C3).

الكلمات المفتاحية: مؤشر جودة التربة ، مؤشر جودة المناخ ، مؤشر جودة الغطاء النباتي, مؤشر جودة الإدارة, مؤشر جودة المياه الجوفية.

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INTRODUCTION

Desertification is defined as the degradation of land in arid, semi-arid, and semi dry environments as a result of a variety of factors, including human activities and climatic variations (11). Desertification is a serious and perilous threat to natural ecosystems. Understanding the spatio-temporal characteristics of this process through the evaluation and monitoring of important indicators appears to be a challenging task (3, 16). Land management is the most blamed desertification agent (4). In addition to wind or/and water erosion, degradation of plant covers and water resources, soil salinization, waterlogging, alkalization, and other natural can all contribute to desertification (5, 10, 13, 14,). Most of the LULC changes were caused by human activities (13).Water body extraction techniques were used to determine decreasing and increasing trends of surface area (1). Unsustainable human activities, such as overgrazing, urbanization, poorly drained irrigation systems, over-cultivation, deforestation, and so on, are currently thought to be the major contributors to speeding up the process of desertification (5, 7). the climate, vegetation, and groundwater quality are the most important drivers for desertification (2). Grazing area and grazing intensity per unit area have significant impacts on grassland desertification (6). Land degradation reduces the production of biomass and vegetation cover for all forms of land use (15) (5).Desertification is a global environmental concern characterized by the loss of biological and economic productivity of irrigated agricultural land, woodland, rangeland, and scrubland due to a mix of human and natural forces (19, 15). Land degradation, a current environmental threat of global proportions, is a complex issue which needs an interdisciplinary approach in order to tackle a given territory's sensitivity to the process, Widely used in the Mediterranean region and other areas worldwide due to advantageous features such as simplicity, flexibility and rapid implementation (17). MEDALUS model published by the European Commission was used for sensitivity evaluation(10). According to studies, desertification affects between (10 - 20) % of the world's dry and semiarid areas (3), and about 41.3 % of the land surface is covered by drylands, which comprise arid, semi-arid, and semi dry zones. A survey of the world's deserts and processes of desertification identifies those that are strictly due to physical factors and those that are anthropogenic (11). Our country depends on oil in the first place, so it requires finding alternatives to benefit from the resources available to us and studying the desert areas, which are very important because they cover large areas of Iraq, including neglected lands such as the Samawa desert. It requires shedding light on these areas and preparing studies to reclaim them to invest them optimally. The Environmental Sensitive Area Index (ESAI) was calculated using five important indices: the Soil Quality Index (SQI), the Climate Quality Index (CQI), the Vegetation Quality Index (VQI), the Management Quality Index (MQI), and the Grand Water Quality Index (GWQI). Data acquisition, storage, management, retrieval, analysis, display, and output are all greatly aided by GIS, it facilitates cross-data analysis techniques and the use of advanced classifications, which improves data interpretation, GIS allows decision-makers to swiftly obtain and analyze transformation phenomena in order to identify and study the appropriate intervention. The objective of our study was to identify the affected areas using GIS tools by mapping desertification.

MATERIALS AND METHODS

Study area: The study area Al-Samawa Badia is located in the south of Iraq the area which is 2693 ha located between the geographic coordinates of 44°52'30" E to 46°59' 33"E, and 29°03'45" N to 31°03'30" N, it is bordered on the South-East by the AL- Saudi border. The climate of Al-Samawa Badia is characterized as arid with an average annual precipitation of 8.42 mm, an average temperature of 24 ◦C and the annual potential evapotranspiration is about 3504,9 mm. The dry period spans from April to October. The main soil order is Aridsols and the sub-order is Gypsids.

Methodology

Environmental sensitivity area index (ESAI): Environmentally Sensitive Areas Index (ESAI) was developed to identify areas vulnerable to the threat of desertification in the "MEDALUS" (Mediterranean Desertification and Land Use) model (19). To assess the environmental sensitivity of desertification five main quality parameters were used including soil, climate, vegetation cover, management, and groundwater. These indices were calculated using the data set shown in Figure (1). The value of each indicator was determined between 1.25 - 1.94, with 1.25 being the least sensitive areas and 1.94 representing the most sensitive areas to desertification (12). Based on sensitivity to desertification, each measure was classified into four categories: low, moderate, high, and extremely high Table (1) (7). ArcGIS software (10.3) was used to show the spatial distribution of each index and indicator. Finally, the geometric mean of indicators was used to assess the total sensitivity of desertification in Al-Samawa Badia, according to:

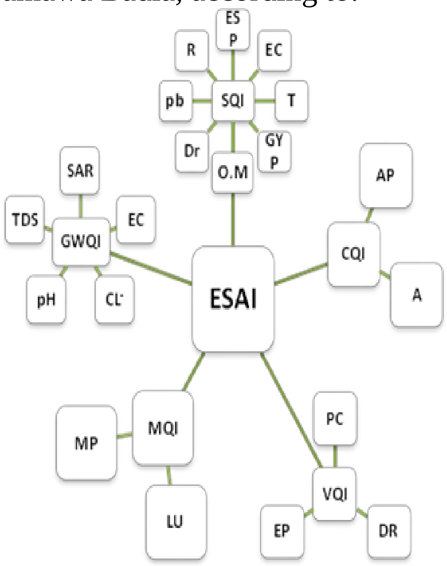

Fig.1 Environmental sensitivity is calculated using these indicators.

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

Where: SQI is soil quality index, CQI is climate quality index, VQI is vegetation quality index, MQI is Management quality index and GWQI is groundwater quality index.

Table 1. Quantitative scores and qualitative classes of considered indices (11)

Classes	Sub-class	ESAI
Non effected	N	<1.25
Potential	P	1.26-1.50
	F1	1.51-1.58
Fragile	F2	1.59-1.67
	F3	1.68-1.75
	C1	1.76-1.84
	C2	1.85-1.93
Critical	C3	1.94<

Soil Quality Index (SQI): The SQI is a main factor in the desertification process, which affects the soil state due to the strength of cohesion between water retention capacity, soil particles, structure, and texture (17) (18). To evaluate SQI, 40 samples in total were collected from a soil depth of 0 –30 cm from different land units. Then, the SQI was computed based on eight parameters including soil electric conductivity (EC), soil gypsum (GYP), soil texture (T), soil organic matter (OM), Rock fragment (R), Drainage (Dr), Bulk Density (ρb) and The exchangeable sodium percentage (ESP). The Soil Quality Index was calculated based on the geometric mean of parameters (9) (13):

$$SQI = (Esp \times Ece \times T \times Gyp \times O.M \times Dr \times \rho b \times R)^{1/8}$$

The attributed rating for each soil indicator is shown in Table (2).

Climate quality index (CQI): The CQI was calculated using two variables: rainfall and the aridity index. The evapotranspiration and precipitation indicators were calculated using data from meteorological stations in the study area. In addition, the aridity index was calculated using annual precipitation and potential evapotranspiration (9). Table (3) shows the rating scores and classifications of CQI indicators. The CQI was determined using the following equations:

$$CQI = (\text{Aridity} \times \text{Annual precipitation})^{1/2}$$

Vegetation quality index (VQI): The VQI was assessed by three different indicators including Plant cover, Erosion protection, and Drought resistance. The classes and weighted scores of vegetation cover indicators are presented in Table (4). The Vegetation quality index was calculated by:

$$VQI = (VeC \times DR \times EP)^{1/3}$$

- plant cover:

$$VeC = 0.65(-4.337\_(3.733 \times NDVI) + 161.968 \times (NDVI)^{0.5})$$

$$NDVI = (NIR - RED) / (NIR + RED)$$

- Drought resistance:

$$DR = \text{yearly annual precipitation} / \text{average temperature}$$

-Erosion Protection:

$$EP = (WEF \times SEF \times SCF)$$

$$WEF = [0.37 \times (silt\% + v.f.sand\%) + (0.28 \times clay\%) + 14.87] / 100$$

$SEF = 1/100[29.09 + (0.31 \times sand\ \%) + (0.17 \times salt\ \%) + (0.33 \times sand/clay) - (4.66 \times OM\ \%) - (0.95 \times CaCo3)]$

$SCF = 1 / [1 + 0.0049\ (clay\ \%)^2]$

Table 2. Rating and Description of SQI (2)

Factors	Description	Characteristic	Rating
Soil texture	Good	L, SCL, LS, CL, SL	1
	Moderate	SC, SiL, SiCL	1.2
	Poor	Si, C, SiC	1.6
	Very Poor	S	2
Drainage	Very Good	Very well-drained	1
	Good	well-drained	1.2
	Moderate	Imperfectly drained	1.6
	Poor	Poorly drained	1.8
	Very poor	Very Poorly drained	2
O.M	Very high	>3	1
	High	3-2	1.2
	Moderate	2-1	1.5
	Low	1-0.5	1.7
	Very low	<0.5	2
EC	Very high	>16	2
	High	8-16	1.8
	Moderate	4-8	1.5
	Low	0-4	1
ESP	Very high	5-8	1
	High	8-16	1.2
	Moderate	16-25	1.6
	Low	25<	2
pb	Moderate	1.2-1	1.4
	High	1.2-1.4	1
	Low	1.4<	2
GYP	Very Good	10>	1
	Good	10-20	1.2
	Moderate	20-30	1.5
	High	30-40	1.8
	Very high	40<	2
R	Big	>60	1
	Moderate	20-60	1.3
	Small	<20	2

Table 3. Rating and Description of CQI (9)

Factors	Description	Characteristic	Rating
Annual precipitation	humid	>500	1
	Moist sub- humid	250-500	1.5
	Arid	<250	2
Aridity	hyper- arid	<50.0	2
	Arid	50-75	1.8
	Semi-arid	75-100	1.6
	Dry sub- humid	100-125	1.4
	Moist sub- humid	125-150	1.2
	humid	>150	1

Management quality index (MQI)

two parameters were studied under the MQI, which are Management Policy and Land-use intensity represented in Table (5).

$$MQI = (Land\ use\ intensity \times Management\ Policy)^{1/2}$$

Groundwater Quality Index (GWQI):

Three samples were taken from wells in the research region to assess the GWQI. Five parameters were used to construct the GWQI: chloride (Cl), sodium adsorption ratio (SAR), pH, total dissolved solids (TDS), and electric conductivity (EC). The GWQI was calculated using the geometric mean of indicators as follows:

$$GWQI = (Cl^- \times SAR \times pH \times TDS \times EC)^{1/5}$$

Table 4. Rating and Description of VQI

Factors	Description	Characteristic	Rating
Plant cover	Very high	100-81	1
	High	80-61	1.2
	Moderate	60-41	1.5
	Low	40-21	1.8
	Very low	20-0	2
Erosion Protection	Low	<0.039	1
	Moderate	0.39-0.053	1.3
	High	0.053-0.066	1.8
	Very high	0.066<	2
Drought resistance	humid	160<	1
	Semi-arid	160-40	1.5
	Arid	40-10	1.8
	hyper- arid	10>	2

Table 5. Rating and Description of MQI (8).

Factors	Description	Characteristic	Rating
Land-use intensity	1	Low land-use intensity	2
	2	Medium land-use intensity	1.5
	3	High land use intensity	1
Management Policy	1	Complete: >75% of the area under protection	1
	2	partial: 75-25% of the area under protection	1.5
	3	incomplete: <25% of the area under protection	2

Table 6. Rating and Description of GWQI (2).

Factors	Description	Characteristic	Rating
SAR	Low	<10	1.4
	Moderate	10-18	1.6
	High	18-26	1.8
	Very high	>26	2
Cl^-	Low	<4	1.4
	Moderate	4-10	1.8
	High	>10	2
pH	Low	<6.5	1.4
	Moderate	6.5-8.4	1.8
	High	>8.4	2
EC	Low	<0.25	1.4
	Moderate	0.25-0.75	1.6
	High	0.75-2.25	1.8
	Very high	>2.25	2
TDS	Low	<450	1.4
	Moderate	450-2000	1.8
	High	>2000	2

RESULTS AND DISCUSSION

Soil Quality Index (SQI): The ρb values ranged from 0.98 to 1.49 mg m^{-3} in the study area. The average gypsum and organic matter of soil samples were 8.6 and 2.1gm/kg, and their maximum was 95.2% and 8.6%, respectively. Furthermore, Ec and Esp values varied from 1.3 - 21.5 ds/m and 2.83- 11.58%, respectively. The texture of the soil in the study area is sandy loam (SL), sand(S), loam

(L), and loamy sand (LS), the sandy loam texture covers 60% of the study area. Moreover, the drainage is well for all the areas. The soil quality index is show in Figure 1. The results showed that 210.8562 ha (7.8%), 1941.17 ha (72.13%), and 539.12 (20.03%) can be classified into low, moderate, and high sensitivity to the desertification of the study area, respectively. The high gypsum content in this area (Figure 2) might cause soil to lose structure and become more vulnerable to water and wind erosion (11), and affected the properties of chemical and physical soil. Also, the SQI indicators showed that organic matter and gypsum are the least and most sensitive to desertification.

Climate quality index (CQI): The entire area is in the very high class of danger for desertification in terms of climate quality index, the climate parameters for the region (potential evapotranspiration and precipitation) do not differ appreciably. In comparison to potential evapotranspiration (7.702 mm per year), the average rainfall in the study area is quite low (0.26 mm/year). So, the results of climate quality indicators showed In terms of precipitation and potential evapotranspiration, the entire area is rated as having very high sensitivity to desertification.

Vegetation quality index (VQI): The situation for vegetation is not excellent due to the dry environment and high salt in the water. Drought resistance (4.067) has the greatest impact on desertification in the area among the vegetation quality indicators and the least sensitive indicator of desertification is erosion protection (0.043-0.13). According to the VQI map (Figure 3), 749.9 ha (27.86%) and 1941.171 ha (72.131%) of the study area are in the low and moderate sensitivity to desertification, respectively.

Management quality index (MQI): In terms of the Management quality index, the whole area is in the very high class of risk for desertification, due to low land-use intensity, which represents the majority of the studied area. so, the study area is classified into high sensitivity to desertification.

Groundwater Quality Index (GWQI): The groundwater in this area is salty, as the electrical conductivity (EC) varies from 3.02 to 3.59 ds/m, with a mean of 3.30 ds/m, the pH values ranged from 7.02 to 7.28, with a mean of 7.15, The total dissolved solids range from 1500 to 1790 mg/L, the average concentration of Cl^- is 290.75 mg/L and the SAR range from 1.39- 2.31 meq/l. The results of GWQI showed that groundwater in the area are not good condition, and is highly sensitive to desertification.

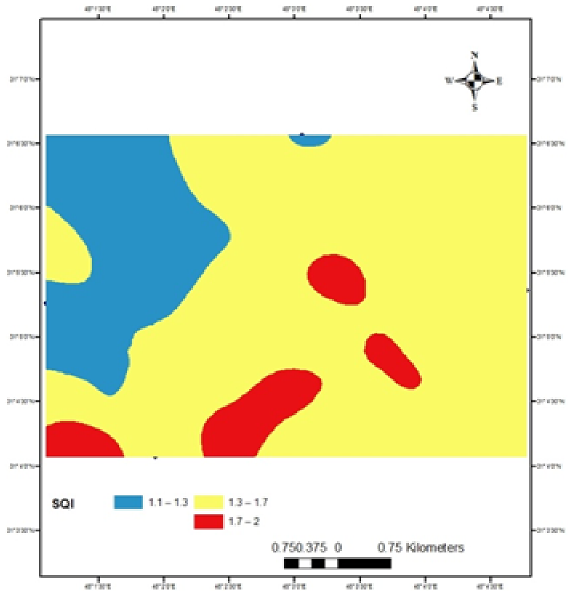

Fig.1 Map of the SQI

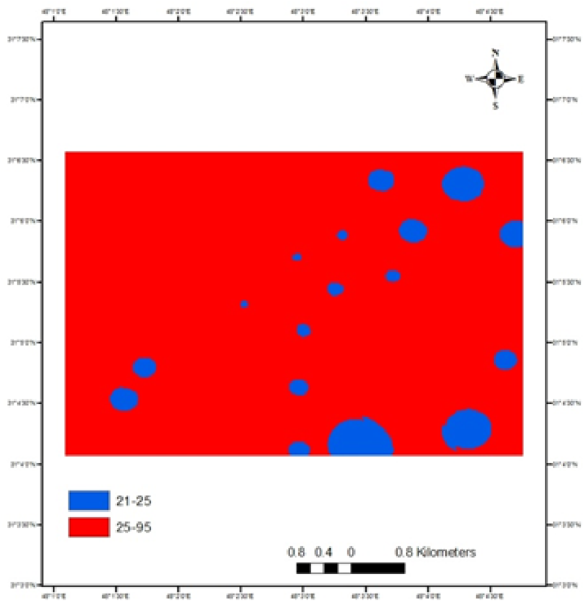

Fig.2 Map of the GYP

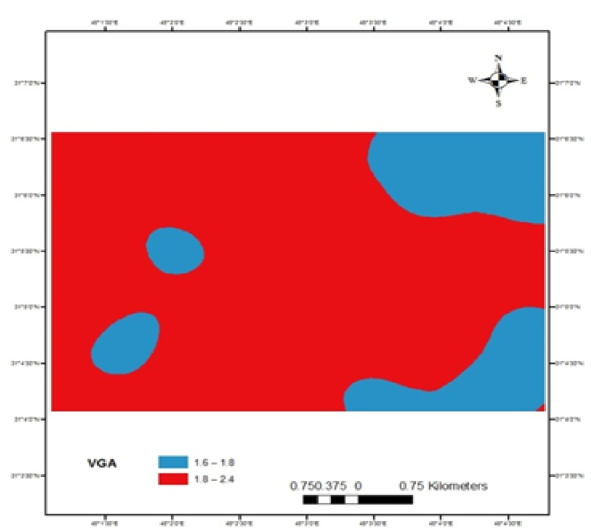

Fig.3 Map of the VQI

Environmental sensitivity area index (ESAI): After averaging the indices the study area is classified as critical to desertification at level C3. Because of the negative effect influence on the climate, management, and groundwater quality for the value of the environmental sensitivity of desertification, this is opposite to the reality of the area. Therefore, the CQI, MQI, and GWQI were excluded from the calculation of the environmental sensitivity index to desertification can be described as shown in Table (7). The map of the ESAI to desertification indicates that classified (None affected (N), Potential (P), Fragile (F), Critical (C)) and the majority of the study area is classified as critical to desertification (Figure 4) at different levels covered an area N: 16.31ha (0.60%), P: 350.12 ha (13.01%), F3: 374.56 ha (13.92), C1: 255.21ha (9.49%) and C3: 1693.03 ha (62.95%). Also, the study area has low organic matter, badly degraded high gypsum levels are very sensitive to low rainfall, climatically constitutes degradation, and is poorly vegetated, causing additional degradation of current land resources. Soil quality has the least impact in the area on desertification.

Table 7. Related areas and percentages of the ESAI for Al Samawa Badia

Class	ESAI	Area ha	%
N	1.14-1.25	16.311	0.606
P	1.25-1.5	350.12	13.01
F3	1.6-1.75	374.56	13.92
C1	1.76-1.84	255.21	9.490
C3	1.93-3.156	1693.03	62.95

CONCLUSION

This study's results showed the majority of the study area is classified for desertification as critical, according to the ESAI. The result illustrates the most essential quality parameters to describe the desertification processes are soil, climate, and vegetation, in the study area. The SQI was low, moderate, and high quality which covered about 7.8, 72.13, and 20.03%, respectively. The vegetation index is low and moderate quality, which represent approximately 27.86% and 72.131 %, respectively. While it was the CQI, MQI, and GWQI in the study area high quality.

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