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ASSESSMENT OF ENVIRONMENTAL SENSITIVITY TO DESERTIFICATION WITH MEDALUS MODEL IN GIS IN MAYMONA PROJECT- SOUTH OF IRAQ

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ABSTRACT

The objective of this study was to identify the locations sensitivity to land desertification based on the Mediterranean Desertification and Land Use (MEDALUS) approach by the Geographic Information Systems (GIS) in the south of Maysan governorate at Iraq for mapping environmentally sensitive areas to desertification. Three indicators, which included climate, vegetation, and soil, were employed to estimate the ESAI and then to classify the land in critical, fragile potentially, and non-influenced sensitive areas. The results of the soil quality index (SQI) indicated that 25% of the studied area was classified as moderate quality and 21% was low quality while 54% was very low quality. Vegetation qualities were classified into moderate and low quality 19% and 81%, respectively, and climate quality was classified as moderate.

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

مجلة العلوم الزراعية العراقية- 2021 :52 (4):1058-1069 حمد وآخرون

تقييم الحساسية البيئية للتصحر باستعمال نموذج MEDALUS في نظم المعلومات الجغرافية لمشروع الميمونة – جنوب العراق

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المستخلص

تهدف الدراسة الى تحديد المواقع التي لديها حساسية مختلفة لتصحر الأراضي على أساس نهج البحر الأبيض المتوسط للتصحر واستعمال الأراضي من خلال استخدام طريقة نظم المعلومات الجغرافية (GIS) لتربة متأثرة بالتصحر تقع في جنوب العراق – محافظة ميسان لرسم خرائط المناطق الحساسة بيئياً بالتصحر. تم استعمال ثلاثة مؤشرات مهمة، والتي تضمنت المناخ والغطاء النباتي والتربة، لتقدير مؤشر المنطقة الحساسة بيئيًا (ESAI) ثم التصنيف الأرض في مناطق حساسة حرجة. أشارت نتائج مؤشر جودة التربة إلى أن 25٪ من المناطق المدروسة مصنفة على أنها متوسطة الجودة و 21٪ منخفضة الجودة بينما 54٪ كانت جودة منخفضة للغاية. صُنفت صفات الغطاء النباتي إلى متوسطة ومنخفضة الجودة 19٪ و 81٪ على التوالي، وكانت جودة المناخ معتدلة.

الكلمات المفتاحية: مؤشر التربة, المناخ, الغطاء النباتي,التصحر في العراق.

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INTRODUCTION

Desertification and drought have become serious problems which caused damaging impacts in many countries in the world, especially those countries which experience dried, semi-dried, or even semi-humid climatic conditions (13). According to the (25), desertification is a process of turning the productive land into desert. Climate change and human activities are important reasons that cause desertification (27). This phenomenon has resulted from land degradation in arid, semi-arid, and sub-humid areas (24). According to the United Nation (27), about 1.2 billion people are at risk from desertification. More than third of the world's land surface area of drylands was degraded. These challenges have greatly worsened in the last two decades rendering environmental, ecological, and economic negative impacts in many countries due to many years of inappropriate soil and water management, declining fertility, climate change, and other factors (13). Desertification is the process of degradation in ecosystems that could be determined by reduced crop vegetation and production, undesirable alterations in the biomass, the diversity of the micro- and macro fauna and flora, and accelerated soil degradation (8). The drylands, which include arid, semi-arid, and dry sub-humid areas, cover about 41.3% of the land surface (18). Desertification is classified into four states: (i) none to slight - with the biological highest production, (ii) moderate - loss of production up to 25% of that expected (iii) severe - loss of production between 25% and 50% of that expected and (iv) very severe - loss of production more than 50% of that expected. Various models have been proposed to evaluate desertification with different approaches and settings methodology for assessment of desertification (9). These models are the model of i) Turkmenistan (1), ii) Glasod (19), iii) MEDALUS (15), and iv) DPSIR-FRAMEWORK (12). Soil degradation is one of the world’s greatest environmental challenges (14). Soil degradation most commonly occurs when erosion, bad soil management, and decreased soil organic matter occurrence lead to reduced crop production (5). Erosion and the loss of soil organic carbon have damaged soils with ~33% of all soils and >50% of agricultural soils degraded worldwide (17). Soil erosion with lower organic matter near the soil surface may cause significant soil degradation within two or three years of the introduction of intensive and continuous cropland management (4). Therefore, soil degradation is of greatest concern, particularly when the soil is not covered by vegetation or the surface is unprotected and directly exposed to the destructive energy of raindrops and other processes and factors (3). According to this review, vegetation cover and erosion are the main processes of land degradation (9). These factors have been recognized as the major driving forces of soil and environmental quality, which has impacted the soil and water resources (28) (4) referred to ability of spectral reflectance to detecting the Aridisols and Entisols orders and can be also detecting sub group at Typic Haplogypsids and Typic Haplosalids taxonomy units appeared to be distinguished and isolated. Environmental sensitivity is considered as an acquired condition, and it is classified into three levels which include i) low-level, ii) normally well-tolerated, and iii) environmental exposures (22). The ESAI was given by the combination of the three important indices which include Soil Quality Index (SQI), Vegetation Quality Index (VQI), and Climate Quality Index (CQI). The SQI, which is used to mapping ESAs, can be related to two important properties which include water availability and erosion resistance. SQI can be evaluated by using some soil properties such as soil depth, soil texture, drainage, parent material, slope grade, stoniness, and etc. The use of these considered properties for defining and mapping ESAs, which requires the determination of distinguished classes of the degree of land protection. The VQI refers to the degree to which the vegetation at a site resembles native vegetation in the absence of human disturbance (11, 20). The CQI is affected using some important parameters that influence water availability to the plants such as the amount of rainfall, air temperature, and aridity, as well as any climate hazards as frost which can probably inhibit or even prevent plant growth. The annual precipitation is classified into three classes considering the annual precipitation of 280 mm as a critical value for soil erosion and plant growth (15, 19). The study was aimed to identify the environmental sensitivity of desertification in the Al-Maymona project in southern Iraq.

MATERIALS AND METHODS

The study site for this study was located at Maysan province at the south of Iraq at latitude (31°46′04 ″.148, 31°27′47 ″.992 N) and longitude (46°52′54 ″.533, 47°02′1 ″.401E).

Data collection

a- Satellite imagery.

Landsat satellite image for Operational Land Imager (OLI) satellite imagery was used, and unsupervised classification was applied to obtain an overview of the spectral differences of the study area as a first step. The results of unsupervised classification were employed to select soil samples using ERDAS Imagine v. 14.

b- Soil samples

Soil samples were collected from Maymona Project which is followed to the Ministry of Water Resources for 2015. Data were georeferenced of 76 profiles, and the database was handled using the ArcMap 10.3 environment. Raster data were converted to vector set of points to be created using IDW approach (16).

c- Normalized differential vegetation index

Normalized differential vegetation index (NDVI) was calculated using the equation 1.

$$\mathbf{NDVI=NIR-RED / NIR+RED \quad \ldots\ldots (1)}$$

Where:

NIR= Near Infra - Red Band R= Red Band

d- Environmental sensitivity area index (ESAI).

The model of MEDALUS was employed to identify the sensitivity in arid and semi-arid regions ecosystems by index of sensitivity to desertification for mapping the ESAI. These are obtained from the geometric average of three indices which included SQI, VQI, and CQI (Equations 2, 3, 4) (Table 1). These indices are affected by the combination of several parameters which are estimated using the computational algorithm according to the following formulas (15, 10):

$$\mathbf{SQI = (ST * PM * S * D * SD * EC * O.M)1/7 \quad \ldots\ldots (2)}$$

$$\mathbf{CQI = (PP * IA * OR)1/3 \quad \ldots\ldots (3)}$$

$$\mathbf{VQI = (FR * EP * DR * PC)1/4 \quad \ldots\ldots (4)}$$

Where:

SQI = soil quality index; CQI = climate quality index; VQI = vegetation quality index; ST = soil texture; PM = parental material; S = slope gradient, D = drainage; SD = soil depth; EC = Electric conductivity; O.M = Organic matter; PP = annual precipitation; IA = aridity; OR = field orientation; FR = fire risk; EP = erosion protection [(EF*SC)^0.5]; DR =drought resistance; PC = plant cover.

EF (Erodibility factor) = 1/100[29.09 + (0.31 * %sand) + 0.17 * %silt) + (0.33 * %sand/clay) - (4.66 * %organic matter) - (0.95 * %CaCO3)]

SCF (Soil Crust Factor) = 1/1 + 0.0049 $(\mathrm{Clay})^2$

Table 1. Classes and weighing indices for soil, vegetation, climate quality assessment*.

Indices	Factors	Description	Characteristic	Rating
Soil quality index (SQI)	Parent material	Good	shale, schist, basic, ultrabasic, conglomerates, unconsolidated	1
		Moderate	limestone, marble, granite, rhyolite, ignimbrite, gneiss, siltstone	1.7
		Poor	sandstone marl, pyroclastic	2
	Soil texture	Good	[1]L, SCL, LS, CL ,SL	1
		Moderate	SC, SiL, SiCL	1.2
		Poor	Si, C, SiC	1.6
		Very poor	S	2
	Soil depth (cm)	Deep	>75	1
		Moderate	31–75	1.2
		Shallow	15-30	3
		Very Shallow	<15	4
	Drainage	Good	well drained	1
		Moderate	imperfectly drained	1.2
		Poor	poorly drained	2
	Slope (%)	Very Gentle	>35	2
		Steep	18–35	1.5
		Gentle	6–18	1.2
		Very gentle to Flat	<6	1
	EC (ds .m^{-1})	Very high	>16	4
		High	8–16	3
		Moderate	4–8	2
		Low	0–4	1
	O.M (%)	Very high	>3	1
		High	3–2	2
		Moderate	2–1	3
		Low	1-0.5	4
		Very low	<0.5	5
Vegetation quality index (VQI)	Fire risk	Low	sand, and Chott Sebkha	1
		Moderate	course, hills	1.3
		Very high	culture, forest	2
	Erosion protection	Very high	mountainous	1.3
		Moderate	course, hills	1.8
		Low	culture sand, and Chott Sebkha	2
	Vegetation cover (%)	High	>40	1
		Low	10–40	1.8
		Very low	<10	2
Climate quality index (CQI)	annual precipitation (mm)	1	>500	1.0
		2	250–500	.0
		3	<250	3.0
	Aridity (mm)	6	>150 (humid)	2.0
		5	125–150 (moist sub-humid)	1.8
		4	100–125 (dry sub-humid)	1.4
		3	75–100 (semi-arid)	1.2
		2	50–75 (arid)	1.1
		1	<50.0 (hyper-arid)	1.0
	Field orientation (OR)	1	NW–NE	1.0
		2	SW–SE	2.0

[*](2, 15)=

[1]L = loam, SCL = sandy clay loam, LS = loamy sand, CL = clay loam, SL = sandy loam, SC = sandy clay, SiL = silty loam, SiCL = silty clay loam, Si = silt, C = clay, SiC = silty clay, S = sand

Vegetation cover = - 4.337-3.733*NDVI +161.968*NDVI 0.5)*0.65 (21)=

Drought resistance (DR) = N / T (2, 15)

Where:

N=total annual rainfall; T= average of temperature

After obtaining the indices values from Table 1, maps of quality index were produced using the IDW approach in ArcMap v. 10.3. The final ESAI was determined as the average of the quality indices from equation 5:

ESAI = (SQI * VQI * CQI)1/3………………….…….……. (5)

Then, the ESAI map was produced using raster calculator and map algebra. Table 2 shows the ranges of three studied indices that include SQI, VQI, and CQI.

Table 2. Ranges of soil quality index (SQI), vegetation quality index (VQI), and climate quality index (CQI)

Indices	Class	Description	Range
SQI	1	high quality	<1.13
	2	Moderate quality	1.20 - 1.30
	3	low quality	1.30 - 1.31
	4	Very low quality	>1.31
VQI	1	high quality	1 - 1.6
	2	Moderate quality	1.7 - 2
	3	low quality	>2
CQI	1	high quality	<1.15
	2	Moderate quality	1.15 - 1.81
	3	low quality	>1.81

Table 3 illustrates the ranges of ESAI for each index of ESAs which includes three subclasses.

Table 3. Ranges of environmental sensitivity area index (ESAI).

Indices	Class	Description	Range
ESAI	Critical	C3	>1.53
		C2	1.45-1.53
		C1	1.38-1.45
	Fragile	F3	1.33 - 1.37
		F2	1.27 - 1.32
		F1	1.23 - 1.26
	Potential	P	1.17-1.22
	Non affected	N	>1.22

RESULTS AND DISCUSSION

1- Properties of soil quality index

a-Soil texture

The results showed that most soils at the study area were moderate texture quality which is sandy clay (SC), silty loam (SiL), and silty clay loam (SiCL). These soil textures cover 68% of the study area because the soils in the study area represent sedimentary soils that are similar to sedimentation conditions and sediment sources. while other soil textures consider a good texture quality loam (L), sandy clay loam (SCL), sandy loam (SL), loamy sand (LS), and clay loam (CL). These textures are considered ideal for agricultural uses such as i) preserve nutrients and 2) retain soil water (23). On the other hand, poor texture quality silt (Si) and clay (C) represent roughly

12% and 20%, respectively (Fig. 1). Sandy soil (S) has the smallest available water-holding capacity and tends to be more prone to drought than clayey soil which maintains less soil water at field capacity (7).

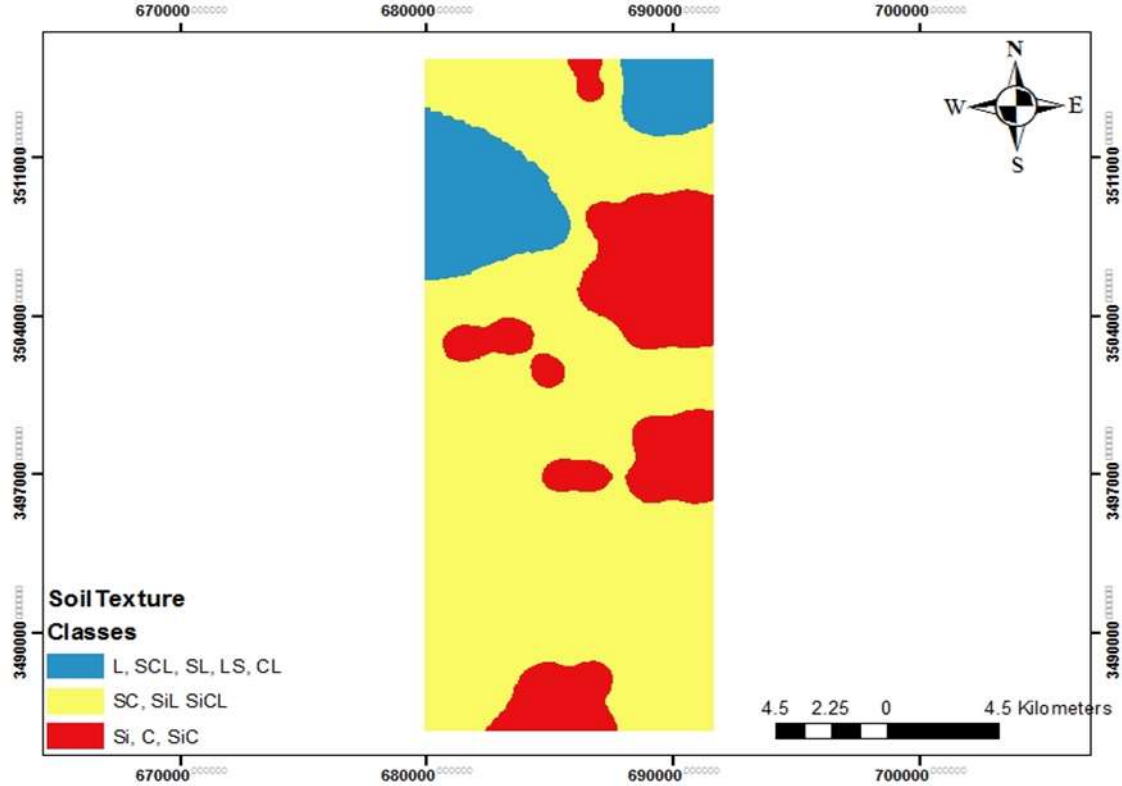

Fig. 1. Distribution of soil texture at study area

b- Soil depth

The results indicated that the entire soil depths in the study area were deep. Thus, it has a quality index of 1 (Table 1).

c-Drainage

The results showed that the property of soil drainage classes in the studied area were poorly drained, moderately, and well drained. These outcomes can be attributed to that the particle size distribution where the finer soil texture represents the slower infiltration of soil. However, most of the soils were medium texture quality.

d-Soil salinity

The results showed that soils were very strongly (>16 dSm^{-1}) which extended over 96% of the study area while about 4% was saline soil (8-16 dSm^{-1}). None saline and slightly saline soils were not found in the study area (Fig. 2). This increase in salinity has occurred due to high temperature and high evapotranspiration, particularly in the summer season. Also, the conditions of poor drainage and electrical conductivity are affected by several factors which include the nature of parent materials, high temperature, high evapotranspiration, topography, and agricultural exploitation. Also, bad management, which includes using traditional irrigation systems, irrigation with low quality water, absence of vegetative cover, intensive agriculture and plowing, erosion, and desertification, for a long-time has significantly influenced the soil salinity and consequently degraded soils.

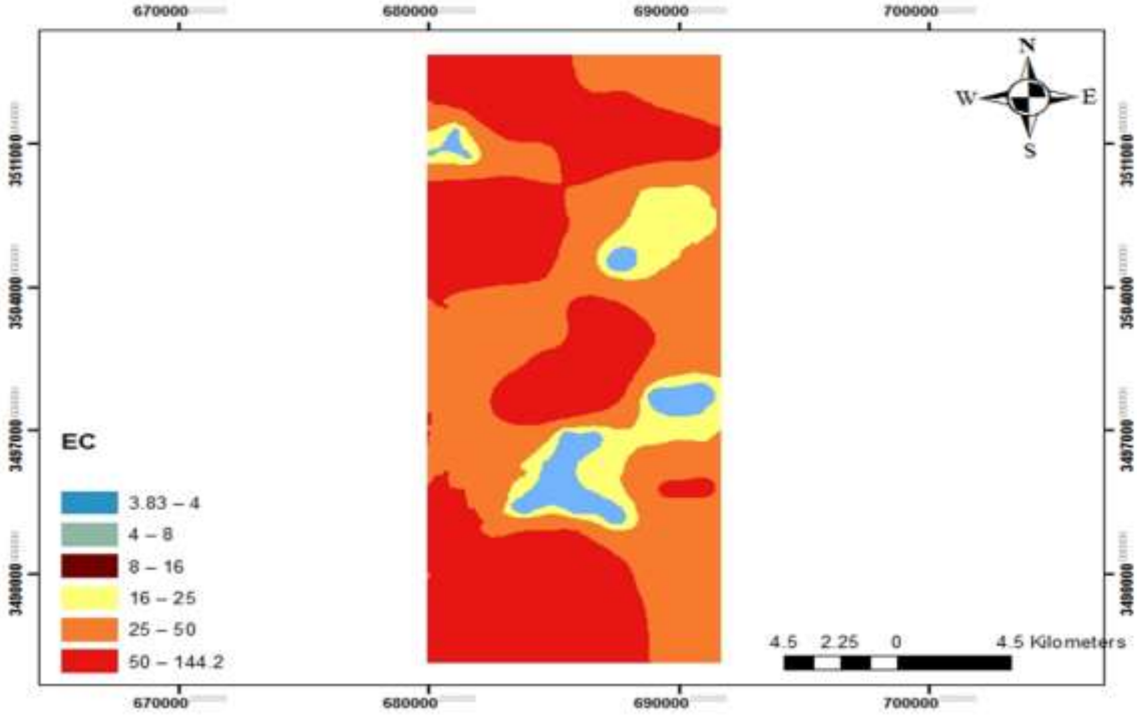

Fig. 2. Distribution of soil salinity levels at study area

e-Organic matter

The results demonstrated that the percent of organic matter was moderate (10 – 20 g.kg^{-1}) which occupied 11% of the study area. On the other hand, lower (5 – 10 g.kg^{-1}) and very lower (< 5 g.kg^{-1}) organic matter represented approximately 70% and 19%, respectively (Fig. 3). Very high and high organic matter was not found in the study area. This can be attributed to human activities that have contributed to decreased contents of soil organic matter and biological activities. However, maintaining and improving soil organic matter, soil microbial biomass, and soil quality may be required to increase the efforts that ensure returning high levels of organic materials to soils with high-residue crops as well as with deep and dense-rooting crops (8).

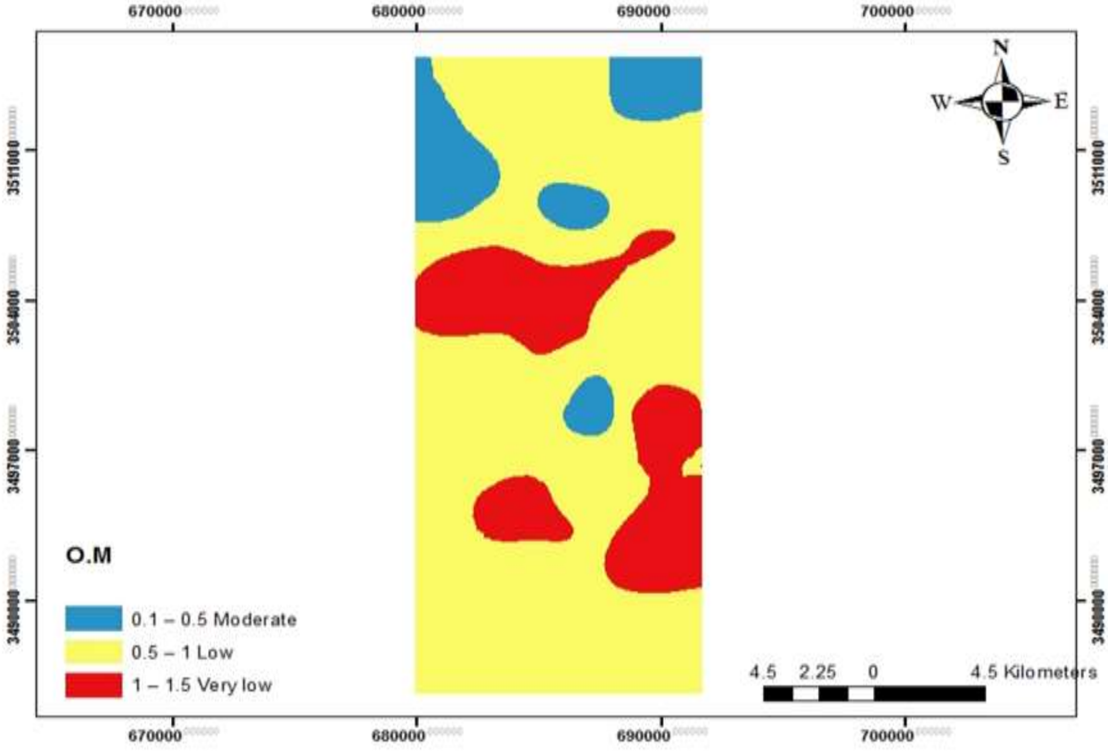

Fig. 3. Distribution of organic matter level at study area

2- Soil quality index (SQI)

The results of the SQI indicated that three classes of SQI have been found in the study area. These classes include medium, low, very low quality and occupied roughly 25, 21, and 54%, respectively (Fig. 4). The map SQI showed that more than 70% of the study area has soils with low and very low quality. These soils encounter environmental, agricultural, and ecological challenges which include higher salinity, lower organic matter, and inappropriate drainage. These challenges have greatly worsened in the last two decades rendering environmental, ecological, and economic negative impacts in many countries due to many years of inappropriate soil and water management, declining fertility, climate changes, and other factors (13). The moderate quality of the soils occupied the area about 25% from the study area, and these soils have low salinity, moderate organic matter, and well to moderate drainage. On the other hand, soils of low and very low quality have high salinity, low organic matter, and poor drainage.

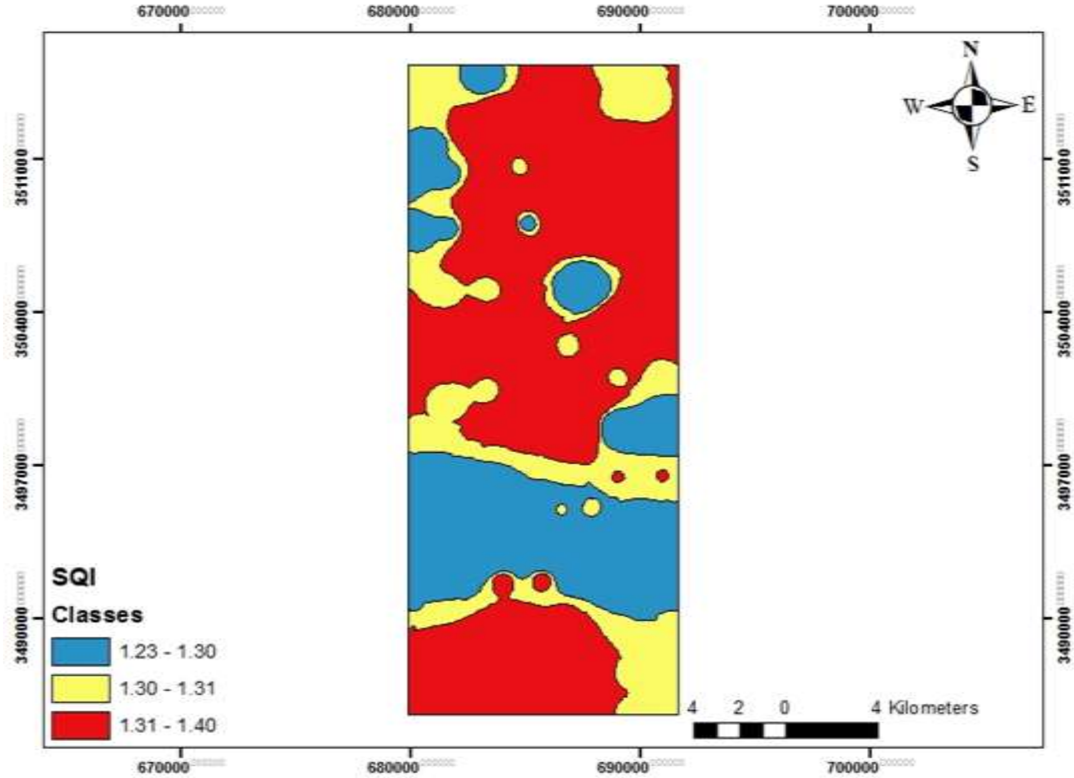

Fig. 4. Distribution of Soil quality index (SQI) at study area

3- Vegetation quality index (VQI)

The results showed that two classes of VQI were found in the Maymona project. The soil for VQI was medium and low quality and occupied approximately 19 and 81%, respectively (Fig. 5). The SQI map shows that more than 70% of the study area has soils of low and very low quality. These soils experience low vegetation and moderate soil Erodibility factor. These factors are affected by the VQI.

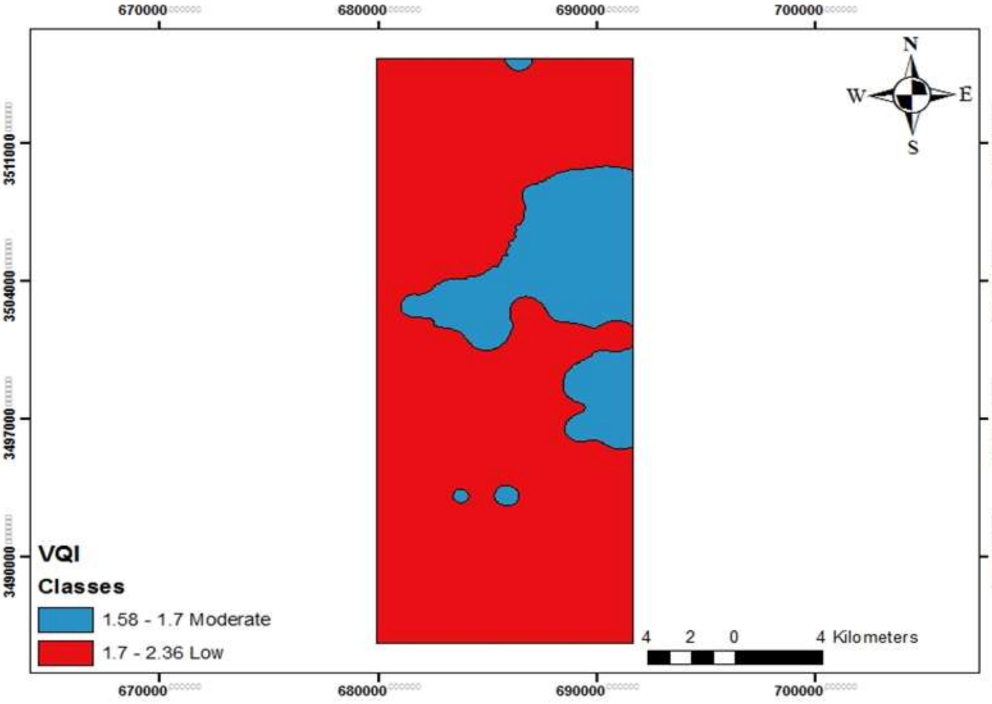

Fig. 5. Distribution of vegetation covers density (SQI) at study area

4- Normalized difference vegetation index (NDVI)

Red light is strongly absorbed by photosynthetic pigments (such as chlorophyll) which found in green leaves, while near-infrared light either passes through or is reflected by leaves tissues, regardless of their color. These results mean that the areas of bare soil having little or no green vegetation and are similar to both red and near-infrared wavelengths. The areas with much green vegetation exhibited more brightness in the near-infrared and are very dark in the red part of the spectrum. The total area for the study area of the vegetation cover extracted by using the NDVI was 34783.7 ha. No vegetation, poor vegetation, moderate vegetation, dense vegetation, very dense vegetation areas were covered 5, 79, 18, 0, and 0%, respectively (Fig. 6).

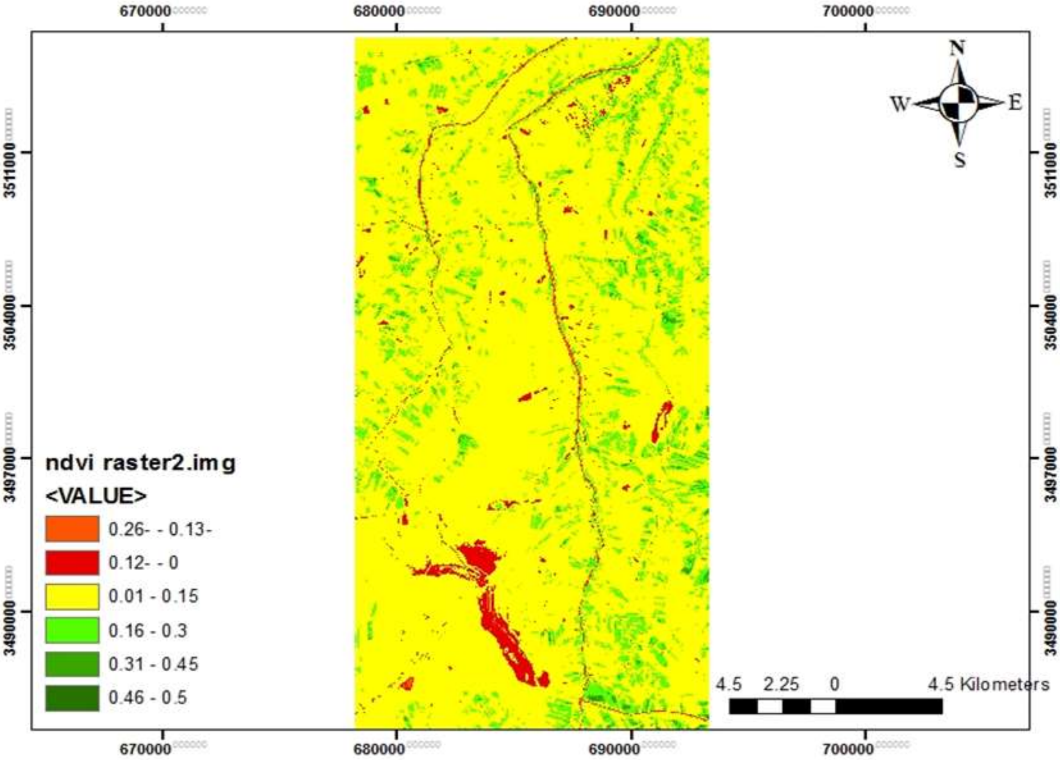

Fig. 6. Distribution of normalized difference vegetation index (NDVI) at study area

5- Climate quality index (CQI)

The climate in Maysan Governorate is considered a desert climate. There is virtually no rainfall during the year. This climate is considered to be BWh according to the Köppen-Geiger climate classification. In Maysan Governorate, the average annual rainfall is 170 mm (<250mm). Therefore, it is classified to semi-arid and field orientation (OR) is North East (NE). The CQI of the study area was 1.44 for all sample sites. This means that the climate quality in the study area was Moderate (Table 2).

6- EEnvironmental Sensitivity Index (ESAI)

The map of the ESAI to desertification indicates that the majority of the study area is classified as critical to desertification (Fig. 7) at different levels (C1, C2, and C3). These findings covered an area estimated at 24, 72, and 4%, respectively. Also, the study area has badly degraded high salinity levels, low organic matter, poorly vegetated, and climatically constitutes a degradation-promoting land use, further deteriorating the existing land resources. The study area is very sensitive to low rainfall.

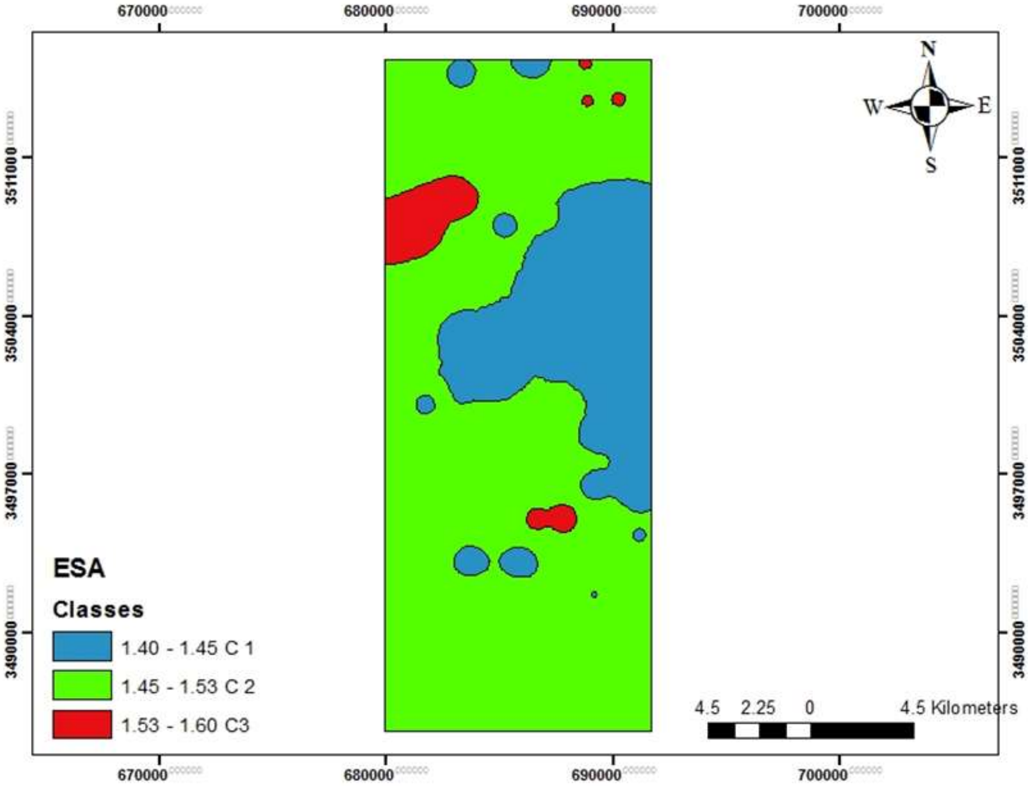

Fig. 7. Distribution of Environmental Sensitivity Index (ESAI) at study area

CONCLUSION

The results of this study illustrated the map of ESAs to desertification showed that the majority of the study area is classified as critical to desertification, while it was moderate and low quality due to vegetation index, which represent approximately 19 and 81%, respectively. The vegetation cover was more than three-quarters of the study area because of the presence of natural. The SQI was a moderate, low, and very low quality which covered about 25, 21, and 54%, respectively. The CQI in the study area was moderate.

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