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Environmental Sensitivity Maps for Desertification and Land Degradation Using Medalus Model and Landsat Image in Salahaldin and Erbil Governorates, Iraq.

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ABSTRACT.

This paper aims to assess the extent of the impact of environmental sensitivity to desertification and land degradation using remote sensing data in the governorates of Salah al-Din and Erbil/Iraq. Thirty soil samples were collected from both sites to assess changes in soil properties and land uses, as well as factors of desertification and degradation such as texture, salinity, erosion, gypsum, and vegetation cover. The sites were identified using GPS. Physical (soil texture) and chemical ($CaCO_3$, $CaSO_4{\cdot}2H_2O$, OM, EC, and pH) properties were estimated. A Landsat image was acquired in April, and the NDVI index and spatial maps were calculated using ERDAS 15 and GIS 10.2. The results showed variations in soil properties such as sand, clay, gypsum, calcium carbonate, and organic matter, reflected in the soil quality index. In Salah al-Din, the soil type was categorized into two types: poor (76%) and moderate (32%). In Erbil, the soil type was categorized as high (1.65%), moderate (97%), and poor (0.5%). The vegetation quality index showed that 73% of the vegetation cover was of average quality. (26)% were of poor quality, while the Erbil site included the moderate quality variety. The results also showed spatial variation in the NDVI index, which ranged from moderate to very high in the Salah al-Din site, while it was moderate to mild in the Erbil site.

Key word: climate quality index, soil quality index, vegetation quality index

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INTRODUCTION

Desertification and land degradation are complex concepts that combine more than one direction in the process of diagnosing and determining their causes, which include environmental, economic, political and social causes. Therefore, we believe that intellectual development and correct rationalization can reduce the risk of desertification and land degradation (Montanarella, 2007). Desertification is defined differently across the globe, but contemporary experts generally agree that it refers to land degradation in arid, semi-arid, and dry semi-humid regions caused by climatic and anthropogenic factors. Soil quality deterioration is a contributing factor to desertification and land degradation, characterized as a process that diminishes the soil's present or future potential to provide a specified quantity. Iraq suffers from different degrees of degradation, but according to reports, the degree of severe degradation constituted 70-60% of the land area and one of the most important degradation problems is soil salinity, especially in agricultural lands irrigated by groundwater (FAO, 2011), (Hussein & Ismaeal, 2024). Various models have been developed employing diverse scales, theories, and indicators to evaluate land degradation rates and classify desertification severity, incorporating the MEDALUS (Mediterranean Desertification and Land Use) model, which calculates the Environmental Sensitivity Index for Desertification (ESAS). Numerous investigations done by these (Khalaf & Hussien, 2021, Kosmas et al., 2014,

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Lavado et al., 2009, Sepehr et al., 2007) corroborated that the (MEDALUS) model had some benefits over other models, as its components may be derived from field and environmental survey reports, along with its superior speed and accuracy in data processing. as its general mathematical equation formula depends on using the geometric average of the characteristics under study instead of the mathematical average, as it is more accurate. This model is based on several variables, including physical/chemical (soil quality deterioration), environmental (vegetation cover quality deterioration), climatic (climate quality), and social (management quality), and some researchers added the water quality index (Bakr, 2012, Mostafa et al., 2020). Numerous studies have used the Medulas model to evaluate environmental susceptibility to desertification in the Anbar desert, using soil quality and plant cover indicators to classify and characterize the soils of Anbar Governorate across various physiographic units (Al-Rawi, 2011 and Al-Juraissi, 2013).(Al-Juraissi et al., 2015) Investigated the degradation of the Iraqi alluvial plain soils, concluding that 45.92% of the area exhibited low soil quality, while 54.08% demonstrated moderate soil quality. This finding aligns with a study conducted by which aimed to identify sites with varying environmental sensitivity to desertification utilizing the MEDALUS model and land use analysis through geographic information systems (GIS). This research focused on soils impacted by desertification in southern Iraq's Maysan Governorate, generating environmental sensitivity maps based on three critical indicators: climate, vegetation cover, and soil. The findings revealed that 25% of the examined areas were categorized as medium quality, 21% as low quality, and 54% as very low quality in terms of soil quality index. Additionally, plant cover was classified as medium quality at 19% and low quality at 81%. (Benabderrahmane & Chenchouni, 2010) The data obtained to assess environmental susceptibility to desertification in Fayoum, Egypt, through Geographic Information Systems (GIS), indicate that the areas most at risk of desertification are located in the southern vicinity of Lake Qarun, encompassing 18.31% of the study area, along with additional sensitive regions. Desertification accounts for 54.09% of the total area. Areas with considerable vulnerability to desertification constitute 27.6% of the total region. The integration of many parameters influencing desertification sensitivity might facilitate effective desertification control planning. The findings indicated that climatic and anthropogenic pressures are the primary determinants influencing desertification sensitivity (Lamqadem et al., 2018). (Lee et al., 2019) examined the quantitative evaluation of land cover vulnerability to desertification in Mongolia using the MEDALUS model and adapted the model for use in Mongolia. The revised MEDALUS technique included nine variables for the years 2003 and 2008. In 2003, southern Mongolia had the most sensitivity to desertification, however in 2008, this sensitivity increased in the western area. The environmental sensitivity score escalated almost fivefold in 2008 relative to 2003, signifying accelerated desertification throughout Mongolia from 2003 to 2008. (Mostafa et al., 2020) performed a desertification sensitivity study in the East Siwa Oasis (1763 ha), Egypt. conducted a study to determine and evaluate the degree of environmental vulnerability to desertification. This research sought to assess the extent of environmental vulnerability to desertification by identifying the causes and indicators directly associated with desertification in southern Iraq. GIS technology was used to identify ecologically sensitive regions affected by desertification. Five critical indicators were utilized: soil quality index, climatic quality index, vegetation quality index, management quality index, and groundwater quality index. The findings indicated that the soil quality index varied from high to low, and the vegetation quality index ranged from medium to bad. Furthermore, the indices for climatic quality, management, and groundwater were all classified in the lowest group. As a result, the environmental sensitivity to desertification (ESAI) values were negatively affected and fell inside the

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critical range of the study area. The management and groundwater indicators were left out of the evaluation of environmental sensitivity to desertification. Four groups were identified, each with subcategories (N, P, F3, C1, C3): untouched, prospective, fragile, and critical. A study was conducted to assess the land's vulnerability to desertification. The Mediterranean Desertification and Land Use Model (MEDALUS) was used to assess the land's susceptibility to desertification. Four quality indicators—soil, climate, vegetation, and management—were identified in order to assess the land's sensitivity to desertification in northern China. By using a population density criteria to exclude towns situated in areas vulnerable to desertification, they improved MEDALUS. By linking priority areas with planned land restoration to support desertification control, the validated framework in northern China improves the model. The results showed that the four indicators influenced and constrained each other. The distribution of susceptibility to desertification in northern China. There were significant regional differences in the spatial distribution of sensitivity in northern China, with clear borders and concentrated regions of high and low sensitivity; overall sensitivity decreased, with some areas that were previously classified as moderate, severe, and very severe sensitivity becoming slightly sensitive; the management quality index weight was substantially higher than the climate, vegetation, and soil indices. This implies that the main factor influencing northern China's susceptibility to desertification was management, while climatic circumstances exacerbated this sensitivity; nonetheless, the mechanisms leading to regional variation need more examination. In another study conducted by (Elaalem & Ezlit, 2020) spatial differences in the GIS environment were mapped using the inverse weight distance method (IDW) for some chemical soil properties, namely the chemical element ratio (ESP), the calcium carbonate ratio ($CaCO_3$), the soil reaction degree (pH), the electric current degree (EC), and the gypsum ratio ($CaSO_4.2H_2O$) in the areas of Ain Belt, Batta Village, Taknes, in northeastern Libya. The results showed that using the inverse weight distance method (IDW) in mapping the chemical properties studied in this study; Because it gave reliable results, which is what distinguishes the quality standards represented in the values of the root mean square error (RMSE) and the coefficient of determination (R^2) for each of ESP, $CaCO_3$, pH, EC and $CaSO_4.2H_2O$, where these values ranged from 0.157, 0.54, 0.045, 0.027, 0.008, 0.94, 0.88, 0.86, 0.85 and 0.83, respectively. This study concluded that it is possible to use the IDW- inverse distance weight interpolation method in mapping and spatial tracking of different soil properties in the study area and similar areas, and then produce interpretive maps for these properties. This study also recommends updating the available data on the soil sectors represented in the study area in order to be able to track them temporally in other future studies. In a study conducted by Fuzzy logic was utilized to transform complex models into simple, comprehensible models that disregard the precision of events or concepts within environmental geographic information systems, facilitating the creation of soil degradation maps for chemical land degradation through spatial interpolation methods. (inverse distance weight). The research aim of study soil /land desertification and degeradation using Medulas paramet and landsat images in Salahadin and Erbile regions.

MATERIALS AND METHODS

Study Area: Two different region were selected in terms of soil characterized, climate conditions and prevailing soil grades. The first site is located in Salah aldin Governorate /AlDour District and is located on longitudes (43' 30" and 43˚ 57' 30") E and latitudes (34˚ 39' 30" and 34˚ 21' 30") N, with a study area 262.77 km^2, and rainfall rates 171.69 mm annually, and the elevation of the study area ranges between 80 and 120 meter according to DEM satellite, and the slope is 7.75%, while the slope is approximately less than 5 degrees (Figure 1). The second site was selected in Erbil Governorate/Koyeh District, which is located between the geographical coordinates (44˚ 9' 0″ and 44˚ 21' 30") E and (36˚ 20' 0.00" and 36˚ 12' 0.00"), with a study area of

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103.594 km^2. Annual rainfall ranges between 172.90 and 163.00 mm per year in January and October respectively, with a total of 672.80 mm per year. The elevation of the study area ranges between 750 and 950 m above sea level, and the slope reached to 25% (Figure 1).

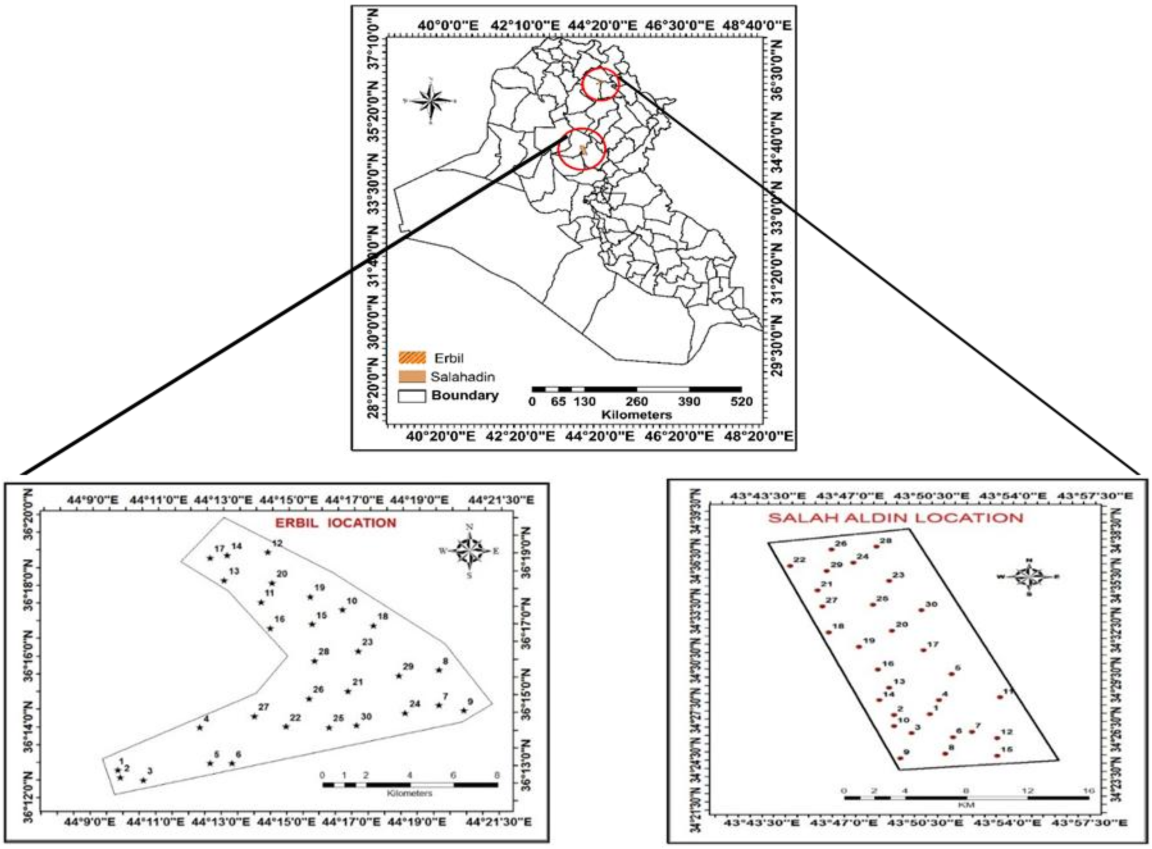

Fig. 1. Map of Study area

MEDALUS Project: Environmental maps depicting desertification and land degradation are delineated using MEDULAS for the examined regions, based on indicators of soil, vegetation, and climate (Kosmas et al., 2014, Lamqadem et al., 2018, Zambon et al., 2017, Mostafa et al., 2020), where in the Soil Quality Index (SQI), Climate Quality Index (CQI), and Vegetation Cover Index (VQI) were employed in the analysis. Spatial distribution maps of soil quality indicators, plant cover, and environmental sensitivity were generated using ArcGIS version 10.2 software. The assessment of environmental sensitivity to desertification and land degradation was conducted utilizing the inverse distance method.

Soil Quality Index

To calculate the soil quality index, eight soil characteristics were selected: soil texture, electrical conductivity, soil reaction, organic matter, fragment condition, relief, gypsum, and calcium carbonate. The index was computed using the following equation:

The Soil Quality Index (SQI) is defined by the equation:

SQI = $(X1 \times X2 \times \ldots \times Xn)^{(1/n)}$ ……. (1),

where X represents the soil properties listed in Table (1).

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Table 1. Categories, descriptions, and allocated weighting indices for the parameter

	Parameter	Class	Description	Susceptibility class	Weight index
	Soil Texture	1	Good	L, SCL, SL, LS, CL	1
		2	Moderate	SC, SiL SiCL	1.2
1		3	Poor	Si, C, SiC	1.6
		4	Very Poor	S	2
	% OM	1	Very high	3>	1
		2	high	2- 3	1.2
2		3	moderate	2-1	1.5
		4	poor	1-0.5	1.7
		5	Very poor	0.5>	2
	EC dSm^{-1} (1)	1	Free	0-2	1
3		2	Slightly	2-4	1.2
		3	moderate	4-8	1.5
		4	Sever	8-15	1.8
		5	Very sever	15<	2
4	% Slope ,(DEM) ArcGIS	1	Level	6%>	1
		2	Gentle	6-18	1.2
		3	steep	18-35	1.5
		4	Very steep	35%<	2
	% $CaCO_3$	1	Very low	3%>	1
		2	Low	3-10	1.2
5		3	moderate	10-25	1.5
		4	High	25-50	1.8
		5	Very high	50%<	2
	ROCK FRAGMENTS	1	Very stony	60<	1
6		2	Stony	20-60	1.3
		3	Bare to slightly stony	20>	2
	$CaSO4.\ 2H_2O$	1	low	2>	1
7		2	moderate	2-10	1.5
		3	high	10-25	1.8
		4	Very high	25<	2
		1			
		2			
	pH	3		6.6-7.3	1
		4			
		5	Neutral		
		2	Slightly alkaline	7.4-7.9	1.2
8		3	Moderately alkaline	7.9-8.4	1.5
		4	Strongly alkaline	8.4-9	1.7
		5	Very Strongly alkaline	9<	2

Vegetation quality index

The primary variables affecting vegetation quality, density, and species composition in the region include erosion (both aeolian and fluvial), terrestrial vegetation cover, and the extent of degradation. Metrics for erosion mitigation, drought resilience, and vegetative coverage. The categorization of plant types and their associated scores were determined using the specified equation (see Table 2).

VQI = (VgC% × Erosion × Drought)$^{\wedge(1/3)}$..(2)

Vegetation Cover - VgC %

The percentage of plant cover was determined using the Porevdorj technique (Porevdorj, 1998), and it ranged from 0% to 100%. ArcGIS Version 10.2 was used to compute the Vegetation Green Cover (VgC) percentage. The NDVI, an indicator that measures vegetation density, health, and growth, was computed using ERDAS software Version 15. Values range from -1 to +1; a value close to 1 indicates higher plant density. The index highlights the difference between the red (B4) wavelength, which has a noticeable absorption band called the Chlorophyll absorption zone,

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and the near-infrared (B5) wavelength, where plants show the highest reflectance.

VgC% = 0.65 × (-4.337 - (3.733 × NDVI) + 161.968 × (NDVI)^(0.5)) …. (3)

The Normalized Difference Vegetation Index is referred to as NDVI in this context.

NDVI is computed using the formula:

(NIR - R) / (NIR + R)…. (4)

Regarding the acquired R-RED (B4 at the OLI, Landsat 8; 9), NIR stands for Near Infrared (B5 at the OLI, Landsat 8; 9). degradation of the soil. Wind erosion, water erosion, and the crust index are among the measures used to assess the erodibility of soil. The following describes the process for calculating the product of three indices.

E = EF × WEF × SCF …..(5) As explained below, EF denotes the soil's wind erodibility, WEF denotes its water erodibility, and SCF stands for the soil crust factor.

Wind-induced soil erodibility (EF). In desert areas with high temperatures and little precipitation, wind erosion is a major problem. Winds traversing large, open terrain on soils increase the risks of wind erosion. The following equations (6) show how the calculation is affected by soil physical and chemical characteristics that either enhance or reduce soil erodibility to wind erosion, such as sand content and structural deficit, or decrease it, such as organic matter and clay. The degradation criteria were divided into four categories: mild, moderate, severe, and very severe.

EF = 29.09 + (0.31 × sand% + 0.17 × silt% + 0.338 × sand/clay% - 4.66 × OM% - 0.95 × CaCO3%)/100 … (6)

Soil erodibility due to water (WEF). Sandy soils have more voids and enable swifter water circulation in contrast to clayey soils. During low-intensity precipitation, sandy soils have less water erosion relative to clayey soils. The predominant precipitation on clayey soils leads to drainage due to the limited micropores. The calculation is dependent upon soil texture as follows (Fryrear et al., 2000):

WEF = (0.37 × (Silt + vfsand %) × (0.28 × Clay %) + 14.87) / 100 …… (7)

- Soil Crust Index (SCF). The soil crust index is negatively correlated with the concentration of clay. A higher clay content is associated with a lower rate of soil crust development, thereby reducing the soil surface's protection against erosion. Crusts demonstrate increased thickness, rigidity, and erosion resistance relative to uncrusted soils. The pace of crustal erosion is contingent upon the intensity of the wind's abrasive forces. The computation is contingent upon the clay content present in the soil as shown below (Fryrear et al., 2000):

SCF = 1 / (1 + 0.0049 × $CLAY^2$)… (8)

- Lang Factor: Based on the relationship between average temperature and yearly precipitation, Richard Lang has developed a climatic categorization. The following formula is used to calculate the Lang climate factor (L):

L = P/T……. (9)

where T stands for the yearly mean temperature (°C) and P for the annual total rainfall (mm).

Table 2. Classes, description, and assigned weighting

index	Class	Description	Susceptibility class	Weight index
Erosion	1	Low	0.039>	1
	2	Moderate	0.039-0.053	1.3
	3	High	0.053-0.066	1.8
	4	Very High	0.066<	2
VgC %	1	Very dense	100-81	1
	2	dense	80-61	1.2
	3	moderate	41- 60	1.5
	4	poor	21 -40	1.8
	5	Very poor	20-0	2
Aridity Index	1	Humid	160<	1
	2	Semi Humid	160-40	1.5
	3	dry	40-10	1.8
	4	Very dry	10-0	2

Climate quality. The data was acquired from the Iraq Meteorological Organization, spanning the years 1980 to 2019.The evaluation of climate quality entails analyzing factors that affect water availability for vegetation, including precipitation, air temperature, and aridity. Annual precipitation is classified into three categories, with 280 mm recognized as a critical threshold

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for erosion and vegetation. The study area exhibits consistent climatic conditions, characterized as arid and semi-arid, exhibiting no fluctuations in temperature or total precipitation; hence, the climatic variable stays consistent across all examined sites (1.67). Table 3 presents the categories together with their corresponding weighting indices for the evaluation of climatic quality. The Climate Quality Index (CQI) was computed using the following formula:

Climate Quality Index = (Rainfall × BGI)$^{1/2}$ …(10)

Where, CQI=1.5 for SALAHALDIN AND 1.3 for ERBIL; BGI= Gaussen-Bagnouls Classification

Table 3. Classes, description, and assigned weighting

index	Class	Description	range	Weight index
Rainfall (mm)	2	Humid	>650	1
	3	Dry-humid	650-280	1.5
	4	Dry	<280	2
BG Index	1	Very humid	<50	1
	2	Humid	50-75	1.1
	3	Humid -Dry	75-100	1.2
	4	Semi dry	100-125	1.4
	5	Dry	125-150	1.8
	6	Very dry	>150	2

ESAI (Environmentally Sensitive Areas Index).: Index of Environmental Vulnerability to Desertification and Land Degradation Employing Multiple Factors (Soil Quality, The quality of the vegetation and climate. separating the region into eight subcategories and four major groupings, as seen in table 4.

ESAI = (SQI *CQI *VQI)$^{1/3}$ (11)

Where, SQI: Soil Quality Index, CQI: Climate Quality Index, and VQI: Vegetation Quality Index.

Table 4. ESA, Soil, Vegetation, Climate Quality

Quality	SOI	VOI	CQI
High	<1.13	<1.13	1.15
Moderate	1.13-1.45	1.13-1.45	1.15-1.81
Low	>1.45	>1.45	>1.81
ESA index			
Degree	Class	subclass	Weight index
1	N	-	<1.17
	P	-	1.22-1.17
3	F	F1	1.26-1.22
		F2	1.32-1.26
		F3	1.37-1.32
4	C	C1	1.41-1.37
		C2	1.53-1.41
		C3	>1.53

N: Non affected; P: Potential; F: Fragile; C: Critical

RESULTS AND DISCUSSION

Soil Quality Index-SQI: In dry and semi-arid locations, the soil's susceptibility to desertification and land degradation is reflected in the regional variations in its qualities. The soil characteristics indicate that the Salahuddin site exhibits an unstable and loose structure, mostly owing to the predominance of sandy texture exceeding 70%, elevated gypsum salt concentrations, sparse and dispersed plant cover, and little organic matter content.Overall, when calculating the index based on soil properties as a final outcome, it was observed that the index values classified the soils in Salahuddin as moderate and poor in quality. The moderate category covered an area of 61.884 km² (32.54%), while the poor category covered 200.97 km² (76.46%).In contrast, the Erbil site

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was classified into high, moderate, and poor quality categories, with the moderate category being the most dominant, covering 101.45 km² (97.93%). The high quality category covered 1.65 km² (1.59%), while the poor category covered 0.49 km² (0.48%) fig.2. The assessment results from the interaction of multiple physical, chemical, and morphological properties, which collectively determine the suitability of the soil for plant growth. Although individual properties may significantly impact soil health, the overall evaluation reflects the soil's resistance or susceptibility to desertification. The soil samples from the Salahuddin site are at risk of desertification, with factors such as organic matter content, calcium carbonate, calcium sulfate, sand content, and electrical conductivity playing a major role. Additionally, mismanagement has further exacerbated soil degradation.

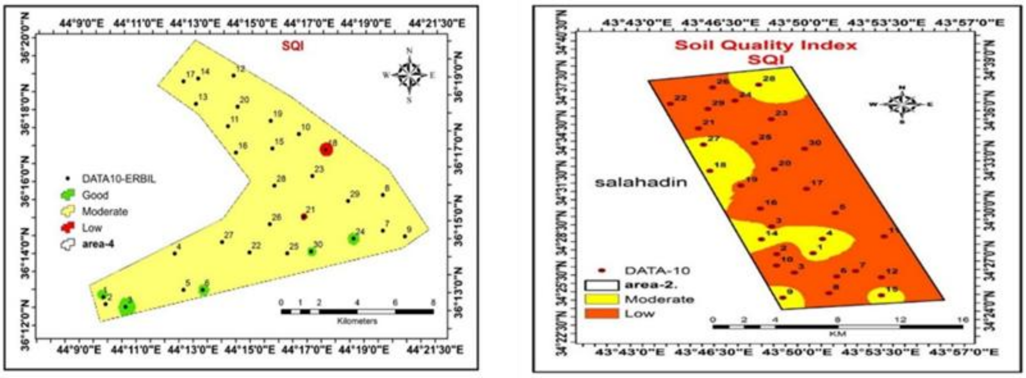

Fig.2. Spatial distribution map of soil quality index taxa in the two study sites

Vegetation quality index-VQI: Erosion index: Soil erosion is a significant factor in assessing desertification and land degradation, as it leads to the loss of soil particles. decrease its fertility and may cover crops when these particles accumulate in lower areas. especially when transporting large amounts of sediments. Therefore, Vegetation plays a significant role in safeguarding the soil surface against erosion caused by both water and wind.

Erodible fraction-EF.

The findings demonstrate a variance in soil susceptibility to wind erosion, correlated with many key soil qualities that enhance the retention of soil particles, hence increasing resistance to wind erosion. It was noted that the highest site for soil susceptibility to wind erosion is the Salah al-Din site, as it was within the Categories include severe, medium, very severe, and low, each defined by a specific area and percentage. The severe category encompassed an area of 154.55 km², representing 58.79% of the total. The medium category covered 83.06 km², accounting for 31.60%. Results indicated that the Erbil site fell within the medium and low categories, with the medium category covering 84.41 km², or 81.48%, while the low erosion category covered 12.05 km².

km^2 and a percentage of (11.64)%. Thus, protecting the soil surface and providing binding materials between its layers reduces the risk of wind erosion (fig.3).

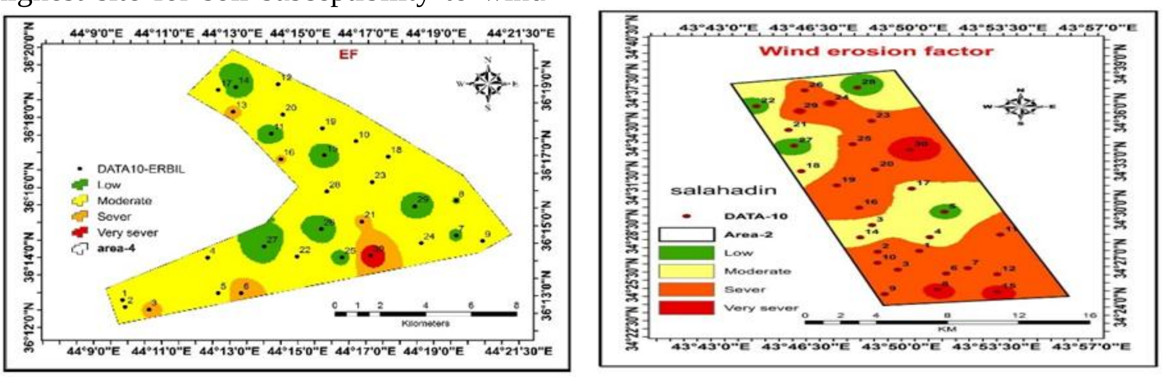

Fig. 3. Spatial distribution maps of wind erosion at the two study sites

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Water erodibility Factor–WEF.

The results showed a variation in the Soil Susceptibility to Water Erosion Index across the study sites. The Salahuddin site fell within the severe and moderate categories, with the severe category covering an area of 182.42 km² (69.40%), while the moderate category covered 53.64 km² (20.41%). Meanwhile, the Erbil site was also classified within the moderate and severe categories, with the moderate category covering 75.21 km² (72.60%) and the severe category covering 16.97 km² (16.39%) Fig .4.This variation may be linked to the soil's content of cementing and binding materials, which contribute to the formation of large aggregates and a cohesive structure. However, based on the figures illustrating soil susceptibility to water erosion, the samples from the Salahuddin site appeared more vulnerable to erosion due to their weak and fragile structure, as well as the dominance of sandy texture—primarily formed by wind activity—giving them characteristics associated with sand dune formation.

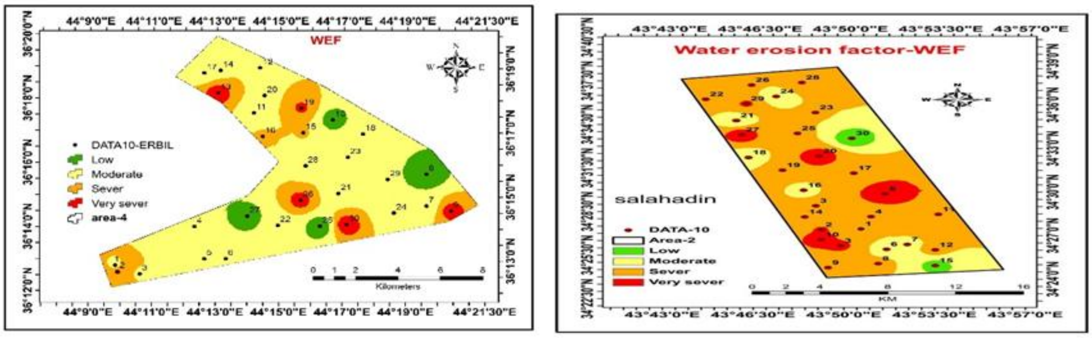

Fig. 4. Spatial distribution maps of the Water Erosion Index (WEF) at the two study sites

Soil crust index-SCI

The results show that the soil crust index was relatively high in sites with relatively weak construction, high gypsum and sand content, which is represented by the Salahaldin site, as the site was within the severe, very severe and moderate degree (73), and the area of the severe class reached 205.86 km^2 (78.32)%, and the area of the very severe degree reached (35.73) km^2 and a percentage of (13.73)%, while the area of the low class reached (18.14) km^2 and a percentage of (6.50)%, while the results indicated that the Erbil site was within the severe and moderate degree, as the area of the severe class constituted (60.09) km^2 and a percentage of (58.00)%, and the area of the moderate class reached (35.37) and a percentage of (34.14)%(fig 5). Consequently, the crust's construction is one of the indicators that safeguard The intensity of winds and precipitation has an impact on the soil surface, resulting in soil erosion and degradation. The development of this crust is contingent upon the clay content; a reduced clay content, which is crucial for structuring the soil and generating aggregates, increases the likelihood of the soil crust fracturing and being susceptible to external influences.

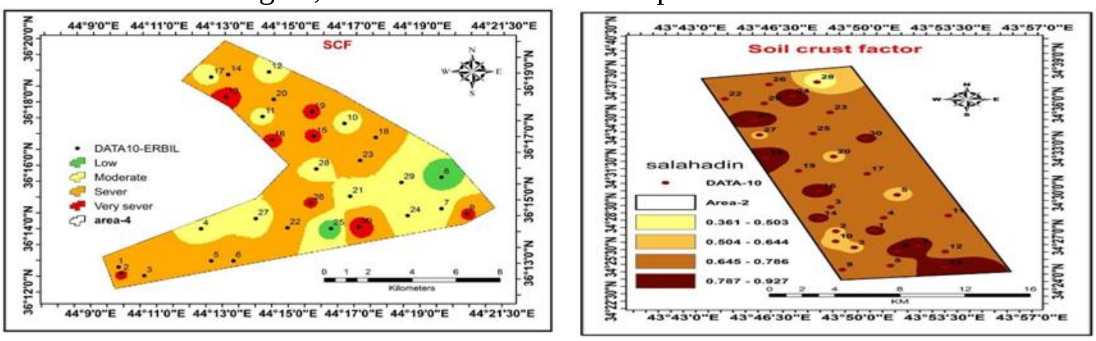

Fig.5. Spatial distribution maps of soil crusting factor for the two study sites

Vegetation green cover-VgC %

Based on the results of the satellite image acquired. The results show that the Salahaldin site was within the poor (low) and moderate class. The area of the low class was 158.89 km^2 (60.45)%, and its evaluation weight was

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1.8, while the area of the moderate class was 100.06 km^2 (38.07)%. The results showed that the Erbil site was within the high and moderate class, and the area of the moderate class was 66.15 km^2 (63.86)%, and the area of the high class was 36.18 km^2 (34.90)%. Therefore, Vegetation cover is a crucial indication and a significant role in the creation and evolution of soils , as sites with high vegetation density will result in an increase in the content of organic matter, humus and the level of fertility elements and improve the quality of the soil(fig.6).

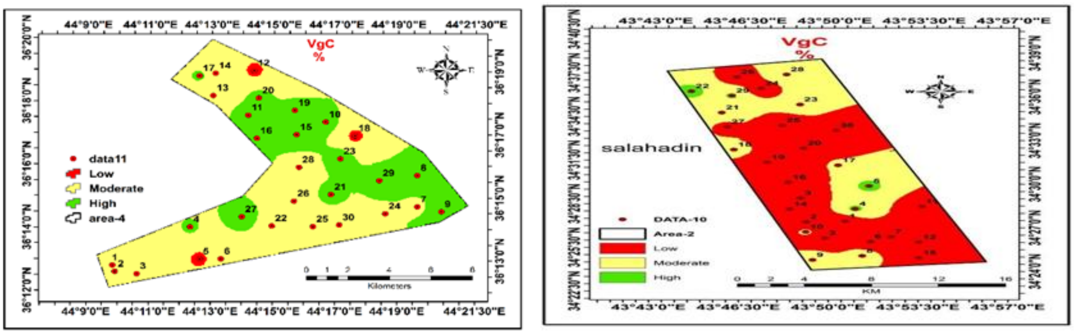

Fig.6.Spatial distribution map of vegetation coverage index VgC% in the two study sites

Vegetation quality index.VQI

The spatial distribution map of the vegetation quality index indicated that the Salah al-Din site was within the poor and moderate quality category, as the area of the moderate category reached (193.28) km^2 and a percentage of (73.53) %. While the area of the low category reached (69.58) km^2 and a percentage of (26.47%).This variation was consistent with the results of the soil quality and its characteristics, in which coarse texture, loose structure, and low ability to retain the moisture content necessary for plant growth prevailed. These characteristics affected the determination of the risk of erosion and the scarcity of vegetation cover, while the spatial distribution map of the Erbil site showed that it was within the moderate quality category, and this is attributed to the type of prevailing climate and the presence of organic matter and vegetation cover. Therefore, Vegetation cover serves as a critical indication and method for combating desertification. In arid and semi-arid regions, the primary source of protection safeguards the soil surface from external forces, enhances internal structure, and maintains equilibrium among essential elements, including air, water, organic matter, microbial activity, soil temperature, humidity, pore distribution, permeability, and organic matter. Figure 8.

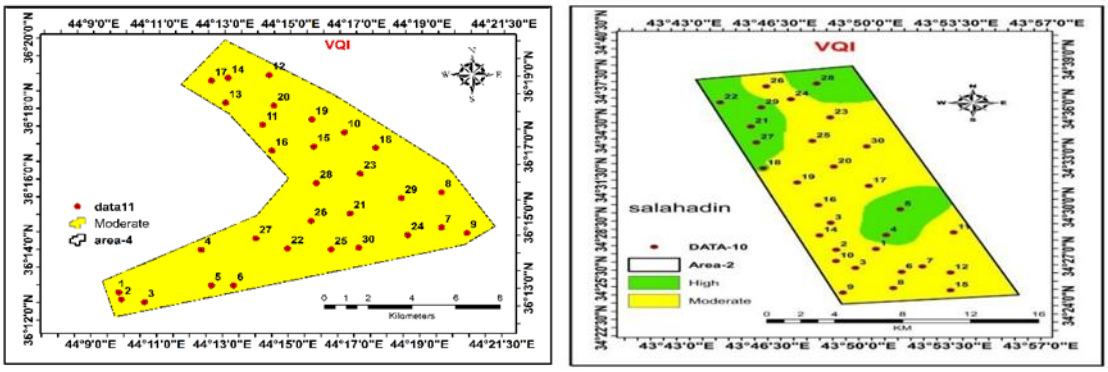

Fig. 7. Spatial distribution maps of the VQI in the study sites

Desertification environment sensitivily-(ESAI).: The results indicated a variation in the values of the environmental sensitivity index to desertification, which is the final result of the factors that affect the degree of desertification, namely soil, climate and vegetation cover. The results showed that the values of environmental sensitivity to desertification in Salah al-Din were within the critical C class and varied according to the degree of the sub-class, and that the Salah al-Din site fell within the C class and the third class C2 and C3, as the area of class C2 reached (95.73) km^2 and a percentage of

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(36.42)%, and the area of class C3 reached (167.12) km^2 and a percentage of (63.58)%. While the results showed that the Erbil site fell within the P class, which is slightly affected, the F class, which is fragile, and under the F1, F2, and F3 classes, where the highest area was recorded for the F1 class, which reached (72.34) km^2, at a rate of (69.83)%, and the F2 area reached (28.15) km^2, at a rate of (27.17)%, and the F3 area reached (0.97) km^2, at a rate of (0.94)% fig.8. Therefore, the study area is highly sensitive to desertification, as a result of the harsh climate conditions, which are a determining factor and have a significant and influential role on plant coverage, soil formation and development, in addition to the deterioration of the physical (texture) and chemical (such as salinity and gypsum) properties of the soil and wind and water erosion factors. Plant density, especially in natural pastures and abandoned lands, is greatly affected by climate. Therefore, plant coverage and its connection to climate will reflect their effect on protecting the soil surface from erosion damage, whether water or wind, which leads to accumulation or drift of the soil surface. This is what we observed at the Salah al-Din site, where there was activity in the movement of sand and its accumulation, especially when barriers were available, which helped to form an area that bears the characteristics of sand dunes, thus becoming a fragile environment that is very sensitive to various desertification processes. On the other hand, poor administrative processes in some areas and the accumulation of salts due to the poor quality of irrigation water move the area towards the highest degree of sensitivity to desertification.

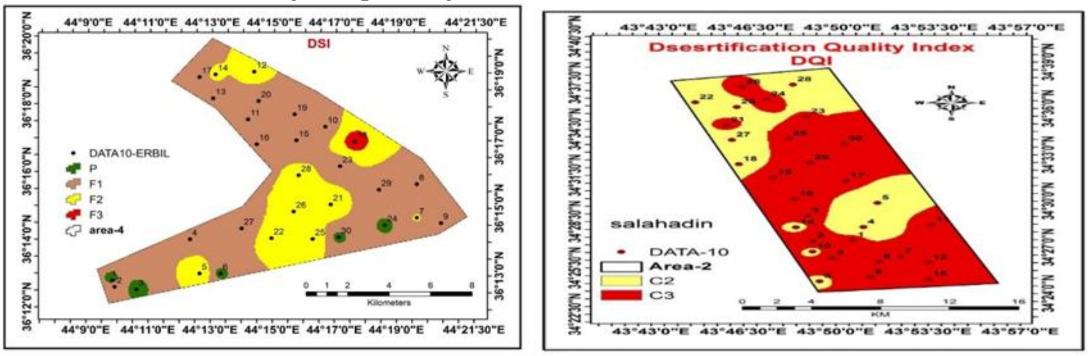

Fig. 8. Map of environmental sensitivity to desertification in the study sites

NDVI index: The visual and spatial analysis of the study area reveals distinct differences in deterioration levels. In the Salah al-Din site, deterioration ranges from very severe at 49.74% to moderate at 17.84%. Conversely, the Erbil site exhibits deterioration levels from moderate at 31.50% to light at 28.99%. The absence of light deterioration with values exceeding 0.3, indicative of high vegetation density, was observed at the Salah al-Din site. This phenomenon may be attributed to the fragile soil conditions characterized by limited rainfall, sparse vegetation cover, and elevated temperatures. The density of vegetation cover is proportional to the amount of rainfall. Reduced rainfall correlates with decreased vegetation density, resulting in scattered plant distribution. Conversely, increased rainfall leads to heightened vegetation density. Figure 9.

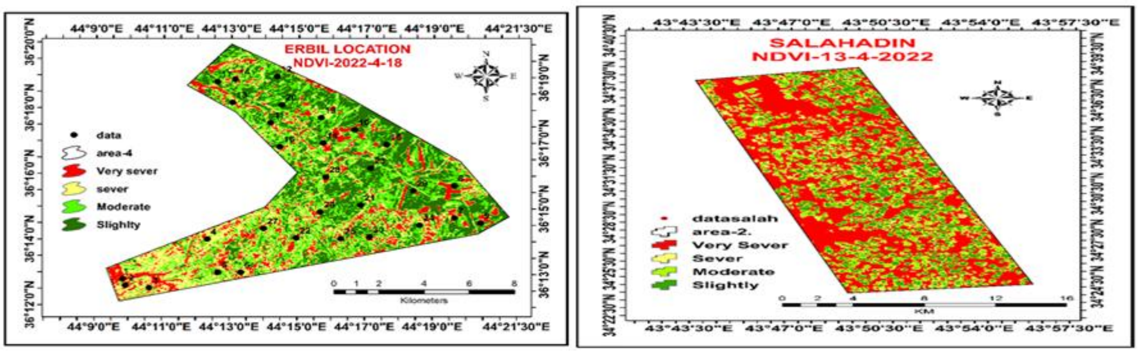

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Fig.9. Map of NDVI in the study sites

CONCLUSION

The study revealed a clear difference in soil sensitivity to desertification between Salah al-Din Governorate and Erbil Governorate. The soil in Salah al-Din was more degraded due to high sand and gypsum content, low organic matter content, and increased erosion.Most of Salah al-Din's soil was classified as poor soil, while average soil quality prevailed in Erbil. The sparse vegetation cover in Salah al-Din increased the risk of erosion and desertification, while the vegetation cover in Erbil provided better soil protection. Wind and water erosion results showed that Salah al-Din was more susceptible to degradation than Erbil. The NDVI index showed severe degradation in Salah al-Din, while degradation was mild to moderate in Erbil. The environmental sensitivity index indicated that Salah al-Din falls within the critical desertification zone, while Erbil was less affected. The study demonstrated the effectiveness of remote sensing and GIS techniques in assessing desertification and creating environmental maps. Climatic factors, sparse vegetation cover, and soil degradation were among the most important causes of desertification in the study areas.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest

DECLARATION OF FUND

The authors declare that they have notreceived a fund.

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خرائط الحساسية البيئية للتصحر وتدهور الأراضي بإستخدام إنموذج MEDULAS ومرئيات لاندسات في محافظتي صلاح الدين واربيل/ العراق.

رؤى قيس محمود ، أياد عبدالله خلف
جامعة تكريت/ كلية الزراعة/ قسم علوم التربة والموارد المائية

المستخلص

يهدف هذا البحث إلى تقييم مدى تأثير الحساسية البيئية للتصحر وتدهور الأراضي باستخدام بيانات الاستشعار عن بعد في محافظتي صلاح الدين واربيل/ العراق. جمعت ثلاثون عينة تربة من كلا الموقعين لتقييم التغيرات في خصائص التربة واستخدامات الأرضي، وعوامل التصحر والتدهور مثل (النسجة، الملوحة، التعرية، الجبس، الغطاء النباتي. حددت المواقع باستخدام نظام تحديد المواقع العالمي. قدرت الصفات الفيزيائية (نسجة التربة) والكيميائية ($CaCO_3$، $CaSO_4.2H_2O$، O.M، EC، pH).تم الحصول على صورة لاندسات في شهر نيسان وتم حساب مؤشر NDVI والخرائط المكانية باستخدام ERDAS 15 و GIS 10.2. أظهرت النتائج تباينًا في خصائص التربة مثل الرمل والطين والجبس وكربونات الكالسيوم والمادة العضوية التي انعكست في مؤشر نوعية التربة والذي شمل في صلاح الدين صنفين وهما الصنف الفقير ومساحته (76) ٪ والصنف المعتدل والذي شكل (32) ٪ من مساحة منطقة الدراسة بينما في موقع اربيل شمل الصنف العالي (1.65) % والمعتدل (97)% والفقير(٠.5)%. وشمل مؤشر نوعية الغطاء النباتي فكانت (73) ٪ متوسط النوعية و(26) ٪ فقير النوعية بينما شمل موقع اربيل على الصنف معتدل النوعية. كما أظهرت النتائج تغاير مكاني في مؤشر NDVI فقد تراوح بين معتدل وشديد جداً في موقع صلاح الدين بينما كان في موقع أربيل معتدل وخفيف .

الكلمات المفتاحية: دليل نوعية المناخ ، دليل نوعية التربة ، دليل نوعية الغطاء النباتي.