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Using spectral indices to assess land degradation in the Wadi al-Muhamadi basin, west of Anbar, Iraq

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***Abstract*---**Land degradation is characterized by the reduction and loss of biological and economic productive capacities of lands. It is a global phenomenon and often has adverse effects at the local level. This study is to assess the state of land degradation in the Wadi al-Muhamadi basin, west of Anbar. Using spectral evidence based on remote sensing data and the results of space data. To assess land degradation and vegetation cover changes in the valley basin, and spectral data (EMI - LDI - DBSI - SI - CI - NDVI) were used to calculate the values of degradation within the lands of the basin. The results showed that the area of barren lands is constantly increasing by 0.02, 52.61 and 42.57% For the study years sequentially. Area of simple improvement with dense vegetation decreased by 0.12 and 0. 16 and 0.42% for the same years, respectively.

***Keywords*---**land degradation, spectral indices, loss biological.

Introduction

Remote sensing contributes to following up on changes in environmental systems, as analyzing the results of satellite visual data using spectral indicators to study land degradation is one of the most prominent modern methods used in detecting changes in vegetation cover. Monitoring and controlling those positive and negative cases and changes (Naji, 2007), and these indicators depend on

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mathematical methods, which are one of the famous and most widely used methods. And conducting several relevant indicators to detect deterioration cases (Al-Mohammed et al., 2018). The study (Mfondoum et al., 2016) aimed to assess the state of land degradation in arid and semi-arid areas by analyzing the correlation between the new spectral and statistical ranges and used the spectral indicators methodology for plants and soil, and the results were interesting to detect land degradation, and the study (Gharbi & Mukhlif, concluded, 2021) Determining four different degrees of deterioration according to the spread of the density of vegetation cover in Anbar Governorate, and they were divided into severe deterioration, moderate deterioration, mild deterioration and non-deterioration. The Euphrates in agricultural areas, and the study recommended expanding studies and research that depend on spectral indicators, specifically vegetation, in the study of land degradation. As for the study (Tao Yu, et al., 2021) it provided many valuable ideas about land degradation monitoring and management in this salty delta and similar conditions in All over the world, land degradation poses a serious threat to the stability and security of ecosystems, especially in saline regions, using several spectral indicators. (Ewunetu et al., 2021) examined the overall land degradation situation in typical highlands of Ethiopia, north of Gogam sub-basin of the upper Blue Nile Basin, to map and measure land degradation of various indicators, as land degradation assessment is a prerequisite for developing efficient land management planning. al-Muhammadi basin in western Iraq using spectral indicators and vegetation cover monitoring for the years 2001-2011-2121).

Materials and working methods

Study area

The Wadi al-Muhammadi Basin is located within the administrative boundaries of (Ramadi, Heet, and Rutba) in the Anbar Governorate in western Iraq, specifically to the south and southwest of the city of Hit. It is located between two latitudes (-33◦ - - 33◦ 60) in the north and longitudes (42◦ 93 - - 41◦ 95) in the east. The area of the basin is estimated at 1971.49 km2. Figure-1.

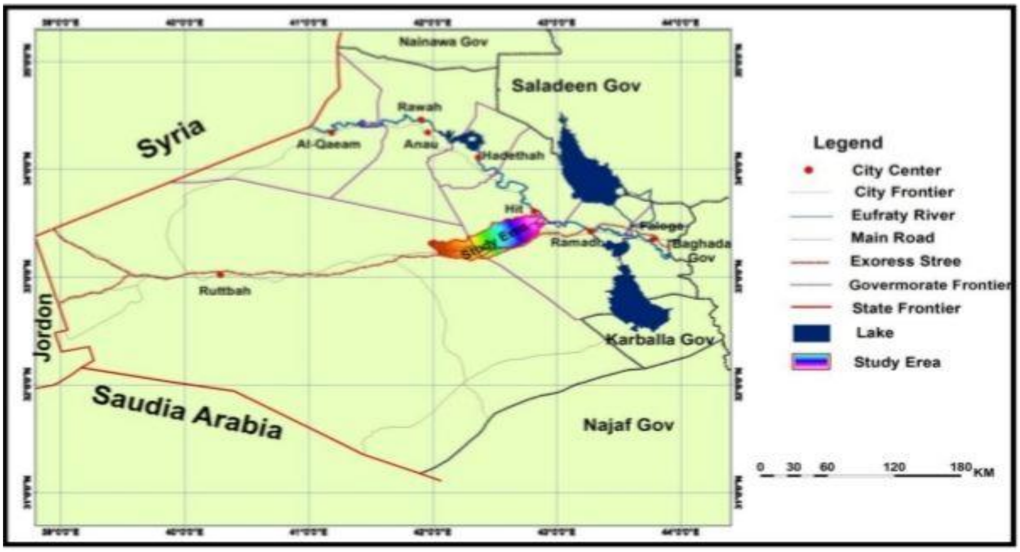


Figure-1: Map of the location of the Wadi al-Muhammadi Basin in relation to Anbar Governorate
Source: General Authority for Survey, Administrative Map of Anbar Governorate, Scale 1/1000000, 2012

Satellite data specifications

The satellite data of the American Landsat series of satellites, including several sensors on board, were used. Three satellite snapshots, captured by the Landsat8 & TM and OLI sensors, were selected across different time series for the years 2001, 2011 and 2021 to study and evaluate the indicators of deterioration and drought in the study area, and through Table-1 Notes the types of satellite visuals used in the research.

Table: 1. Satellite images used in the study of the Landsat satellite

History of satellite visuals	Sensor type (SENSOR_ID)	Satellite (SPACECRAFT_ID)
2/4/2001	TM	Landsat-5
14/4/2011	TM	Landsat-5
9/4/2021	OLI_TIRS	Landsat-8

How it works

- Determining the study area: visualizations of the study area were determined for different years and for the same coordinates. The process of merging the bands and the work of the mosaic was carried out in the program (ERDAS.14), and the production of maps and practical applications was conducted in the program (Arc GIS 10.81.1) within its internal extensions, such as the program (Arc Map) and applications others within the programme.

- Analysis of satellite visuals: Landsat type for the years 2001, 2011 and 2021 for the Muhammadi Basin region. And its source from the official website of the US Geological Survey (USGS Global Visualization Viewer).

Analysis of spectral indicators

First, the normal vegetative divergence index

The Normalized Difference Vegetation Index (NDVI)

The work of the indicator depends on the infrared and infrared rays, the areas where vegetation cover is in its best condition, the chlorophyll in the leaves of the plants works to absorb the red rays, on the contrary, in the areas without plants or in its poor condition, they reflect the infrared rays, and therefore the lands that are located It has vegetation cover that differs in its spectral characteristics from areas and lands that are vacant or almost devoid of plants (Al-Fahdawi, 2019), and the values of this indicator range between (+1) (-1), if the result (+1) indicates the presence of good vegetation cover and that The decrease in these values indicates the exposure of the vegetation cover to deterioration, and this indicator is calculated according to the following equation (Rouse, 1974:

NDVI = (NIR- RED)/ (NER+ RED)............ (1)
Landsat TM , NDVI = (Band 4 – Band 3)/(Band 4 + Band 3)
Landsat OLI , NDVI = (Band 5 – Band 4)/(BAND 5 + Band 4)

Second: Crust Index (CI)

The indicator monitors the crust of the earth's surface of the thin impermeable layer, which is one of the forms of physical degradation of the earth. The thickness of the surface of the earth's layers varies according to the nature of the soils of the clay, lime or sandy region. It is also used to identify the thin layer of soils containing bacteria, lichens, algae, plants and fungi, which is the main component of the ecosystem. Which helps to stabilize the soil and its resistance to water and wind erosion, and the indicator depends on the difference between the red rays range (RED) and the blue rays range (BLUE), and the index values range between (0-2) and (1-2) when the red ray range is less From the range of blue rays of deterioration, this indicator is calculated according to the following equation (Grimm, 2003:

CI = 1- (RED – Blue) / (RED + Blue) .... (2)
Landsat TM , CI = 1- (Band 3 – Band 1)/(Band 3 + Band 1)
Landsat OLI , CI = 1- (Band 4 – Band 2)/(Band 4 + Band 2)

Third: Salinity Index (SI)

It is one of the forms of land degradation due to the high concentration of salts and the high level of salinity on the surface of the soil, and it has negative effects on soil quality and plant growth. The indicator depends on the range of green (B3), red (B4 and blue (B2) rays. The salt index index for the study area was calculated and calculated for the years (2001, 2011, 2021) to estimate and calculate the area of land affected by salts and it was calculated according to the following equation (Othman, 2013:

SI = (GREEN + RED)/2 .... (3)
Landsat TM , SI = (Band 2 + Band 3) / 2
Landsat OLI , SI = (Band 3 + Band 4) / 2

Fourth: Degradation of Baring soil index (DBSI)

The indicator was applied to assess the cases of wind erosion in the area and to give a complete picture of the vegetation cover with low density or high soil reflection. The dynamic range of the indicator ranges between (+2) and (-2). The indicator was applied according to the following equation (Khalaf, 2012):

DBSI = (SWIR – GREEN)/(SWIR + GREEN)- NDVI (4)
Landsat TM , DBSI = (Band 5 – Band 2)/(Band 5 + Band 2) – NDVI
Landsat OLI , DBSI = (Band 6 - Band 3)/(Band 6 + Band 3) – NDVI

Fifth: Land Degradation Index (LDI)

It means the loss of productive and biological capacity and the exposure of land to degradation due to the impact of natural and human factors and bringing the soil to a state of degradation. Soil degradation in order to maintain resource development and ecosystem support in order to meet the needs of current and future generations because it determines the impact of degradation and trying to find a balance in order to reduce soil stress and improve treatment of degraded lands to maintain sustainable development (United Nations, 2016) and the indicator was calculated according to the equation The following (Ibrahim et al., 2017):

LDI = (GREEN + RED)/(GREEN +RED) .... (5)
Landsat TM , LDI = (255 –(Band 2 + Band 3)/(255 + (Band 2 + Band 3)
Landsat OLI , LDI = (65535 – (Band 3 + Band 4)/(65535 + (Band 3 + Band 4))
because
LDI = Soil Degradation Index
Green = represents the green band
Red = represents the red band
65535 = constant value
255 = constant value

Results and Discussion

Land degradation assessment results based on spectral indicators

NDVI vegetative divergence index results

NDVI was used as an important criterion for assessing the state of deterioration by analyzing the vegetation cover in terms of density, area, greenness and its prevalence to assess the state of deterioration. The barren lands recorded the highest percentage in 2011 (52.61%), while the lowest area was in 2001 with

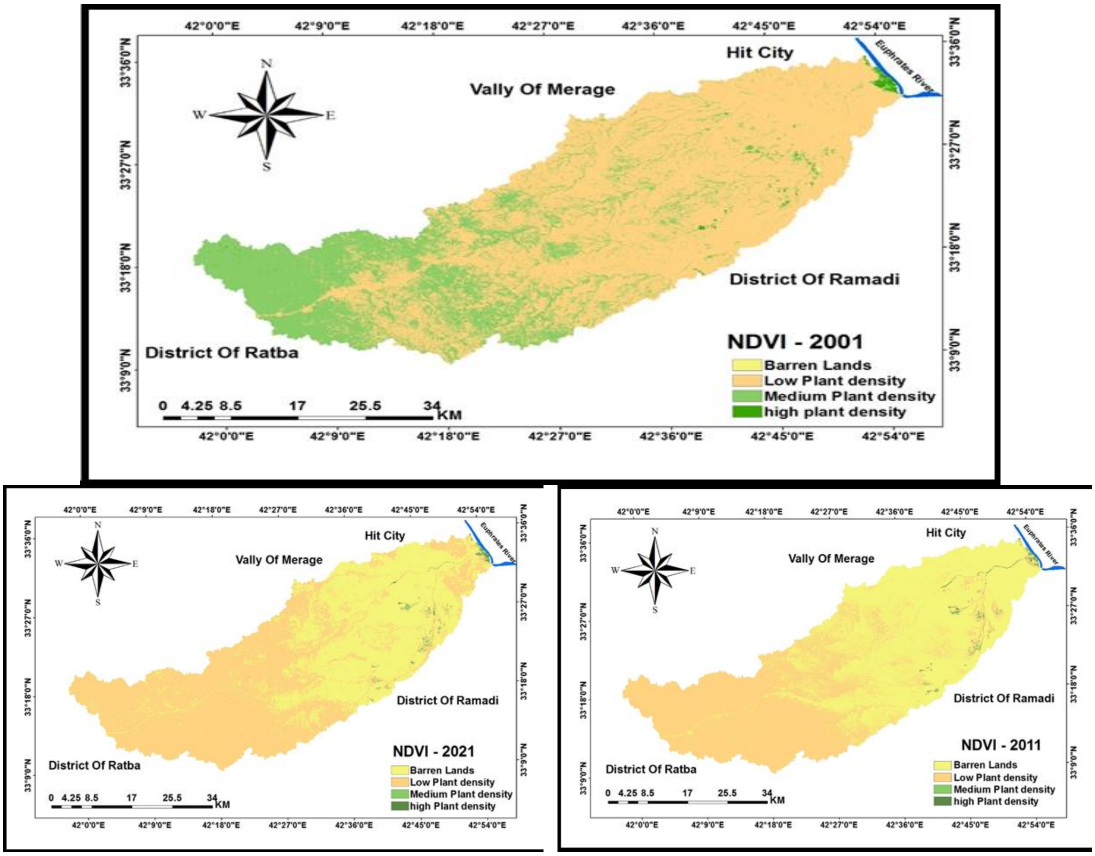
(0.02%), which falls within the severe deterioration category. 70.07, while it formed the lowest area in 2011 with a percentage (46.59%), which falls within the category of medium deterioration. The third and fourth category represented the least areas for all years of the study, and the highest area of the third category recorded the average plant density in 2001 with a percentage of (29.49 %) and recorded the lowest area of the year 2011 with a rate of 0.55%) that falls within the category of light deterioration. As for the fourth category, the good plant density formed the highest area in 2001 with a percentage of (0.42%) and the lowest area in 2021 with a percentage of (0.12%), which falls within the category of simple improvement, and that the events witnessed by Iraq between (2003-2011) was one of the main reasons for the increase in the percentage of barren lands to (52.61%) of the total area of the valley, while the state of deterioration from (2011-2021) was less due to the lack of rain and the prevalence of drought in Iraq, and represents the general state of deterioration Due to several factors, including climatic extremes represented by high temperatures and fluctuations in rainfall, in addition to human factors.

Table 2: NDVI vegetative divergence index for the years 2001-2011-21

NDVI values for years		vegetation density	degree of deterioration	Area km2	The ratio %
2001	0.10- - 0.30-	barren lands	severe deterioration	0.44	0.02
	0.15 - 0.11-	Low plant density	Medium degradation	1381.52	70.07
	0.20– 0.16	Medium plant density	slight deterioration	581.31	29.49
	0.59 – 0.21	Good plant density	simple improvement	8.22	0.42
2011	0.10- - 0.22-	barren lands	severe deterioration	1037.20	52.61
	0.08- -0.11-	Low plant density	Medium degradation	920.46	46.69
	0.15 – 0.09-	Medium plant density	slight deterioration	10.76	0.55
	0. 59 – 0.16	Good plant density	simple improvement	3.01	0.16
2021	0.082- - 0.036-	barren lands	severe deterioration	839.33	42.57
	0.12- -0.083-	Low plant density	Medium degradation	1118.11	56.71
	0.20 – 0.13-	Medium plant density	slight deterioration	11.55	0.59
	0.41 – 0.21	Good plant density	simple improvement	2.49	0.12

Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Figure 2: NDVI maps of Wadi Muhammadi Basin for the years 2001 - 2011 – 2021



Source: TM&OLI Satellite Imagery Analysis, 30m Resolution, Landsat 5&8, 2001, 2011 and 2021,

Results of the Biological Cortex Index CI

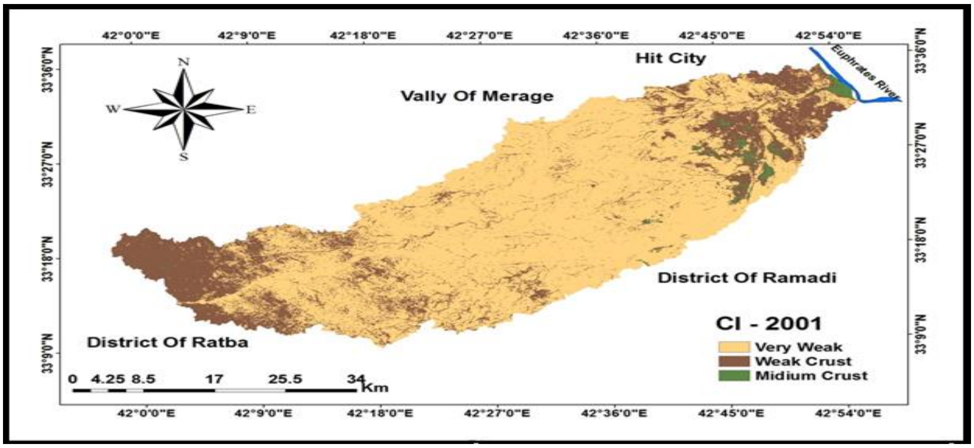
The biological crust index represents the extent of the soil moisture and the dryness of the area. It is clear from the results from Table 3 and Figure 3. The basin is classified into three categories: very weak, weak crust, medium crust. The first class, very weak, recorded the highest area in 2001 with a percentage of 74.13 %) and the least area In the year 2021 with a percentage of 47.58 (%), represented by the severe deterioration class, while the second class weak crust formed the highest area in 2021 with a percentage of 45.24 (%) and the lowest area in 2001 by 24.70%) within the degree of moderate deterioration, while the third class recorded the medium crust with the highest area In the year 2021 by 7.18 (7%) and the least area in 2001 by 1.17%), which represents the degree of slight deterioration.

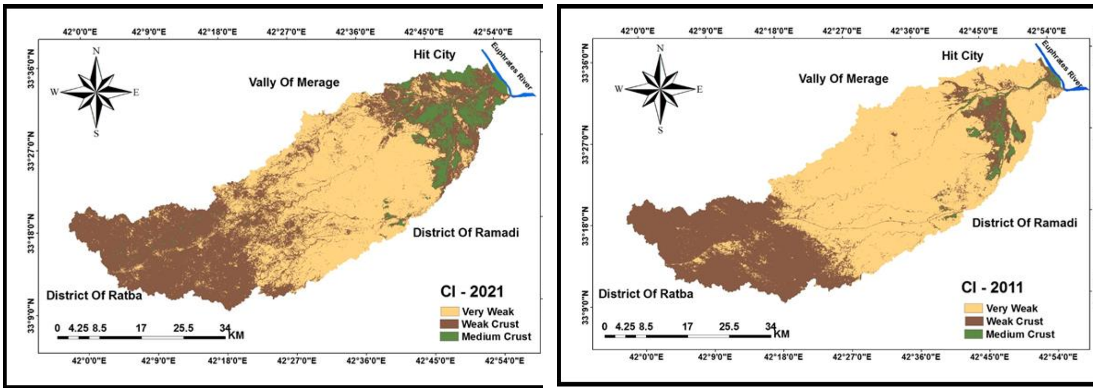
Table 3: Biological cortex index CI for the years 2001 - 2011 – 2021

CI values for years		Biological cortex index	degrees of deterioration	Area km2	The ratio %
2001	less than 0.75	Very weak	severe deterioration	1461.56	74.13
	0.85 – 0.76	weak crust	moderate deterioration	486.87	24.70
	0.99 – 0.86	medium crust	slight deterioration	23.06	1.17
2011	less than 0.75	Very weak	severe deterioration	1235.1	62.67
	0.85 – 0.76	weak crust	moderate deterioration	695.53	35.28
	0.99 – 0.86	medium crust	slight deterioration	40.35	2.04
2021	less than 0.75	Very weak	severe deterioration	938.008	47.58
	0.85 – 0.76	weak crust	moderate deterioration	891.91	45.24
	0.99 – 0.86	medium crust	slight deterioration	141.57	7.18

Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Figure 3: CI maps of the Wadi Muhammadi Basin for the years 2001 - 2011 – 2021





Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

SI . Salinity Index Results

Soil salinization is one of the most important reasons affecting land degradation and one of the environmental problems in arid and semi-arid areas, as well as its direct impact on agricultural lands. It was recorded in 2001 with a percentage of (10.82%), while the lowest area was recorded in 2021 with a percentage of (0.29%) within the degrees of mild deterioration. As for the second category, medium salinity reached the largest area in 2021 with a percentage of (47.58%), while the lowest area was recorded in 2011. At a rate of (35.66%, which represents the degree of moderate deterioration, while the high salinity category, which represents the degree of severe deterioration, spread most of the area and recorded the highest area in 2011 with a rate of 62.59%) of the total area of the valley, while the lowest area was recorded in 2001 with a percentage of (50.4%). The reason for the high salts is the high temperatures and the increase in evaporation that affects the concentration of salts in the soil surface.

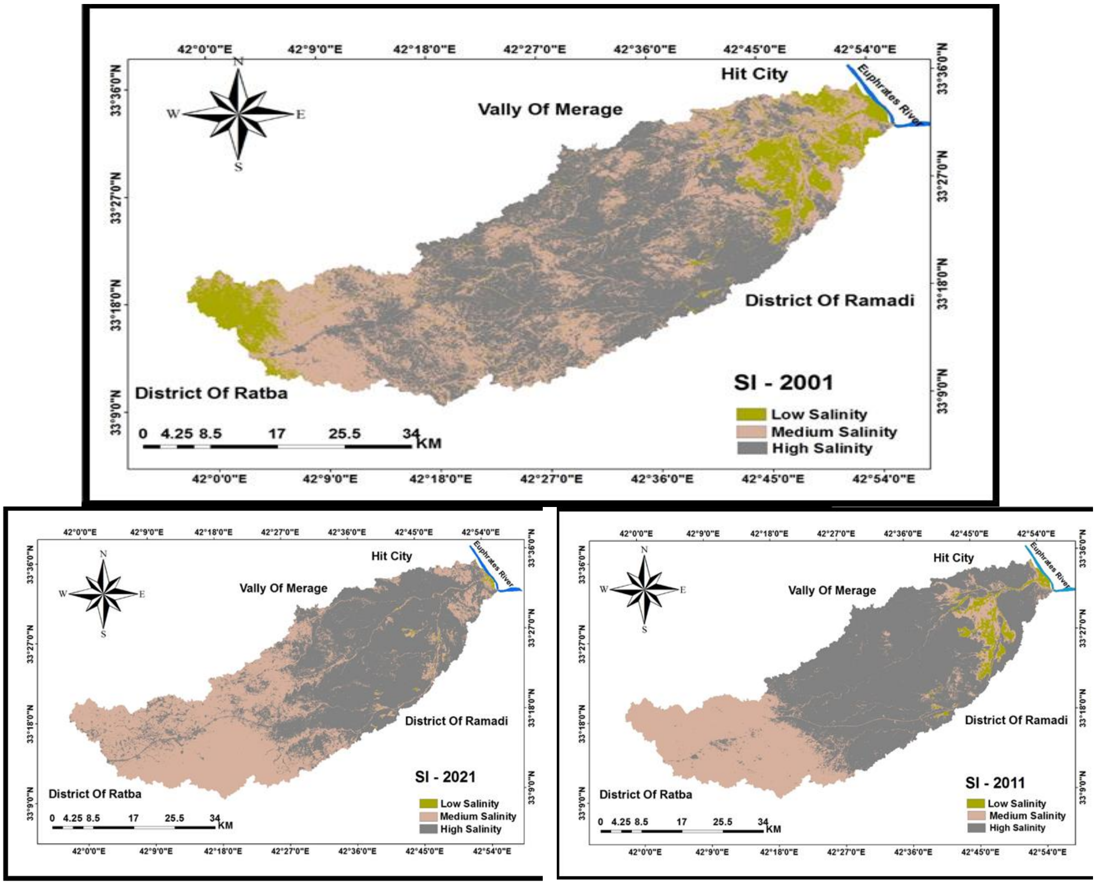
Table 4: SI salinity index index for the years 2001 - 2011 – 2021

SI values for years		salinity index	degree of deterioration	Area km2	The ratio%
2001	84 – 30.5	low salinity	slight deterioration	213.28	10.82
	97 – 85	medium salinity	moderate deterioration	763.35	38.72
	159 - 98	high salinity	severe deterioration	999.87	50.46
2011	97 - 40	low salinity	slight deterioration	54.15	2.75
	123 - 98	medium salinity	moderate deterioration	703.08	35.66
	170 -124	high salinity	severe deterioration	1214.26	61.59
2021	100 – 41	low salinity	slight deterioration	5.80	0.29

	140 – 101	medium salinity	moderate deterioration	937.99	47.58
	177 – 141	high salinity	severe deterioration	1027.70	52.13

Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Figure 4: SI maps of the Wadi Muhammadi Basin for the years 2001 - 2011 – 2021



Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

DBSI Erosion Index Index Results

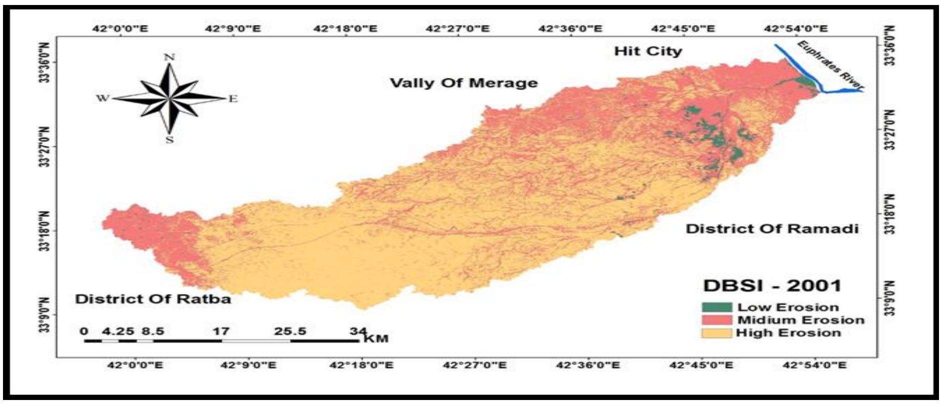
The indicators represent the nature of erosion, meaning wind and water erosion, and wind erosion in dry and semi-arid areas has the most impact on soil erosion. The study area was classified according to the indicator into three categories (slight erosion, medium erosion, high erosion), and it appears from the results of Table 5 and Figure 5, The first category is minimally erosion, which recorded the highest area in 2021 with a rate of 3.33%) and the lowest area was in 2011 0.82%) falls within the category of minor deterioration, while the second category, which is medium erosion, recorded the highest area in 2011 with a rate of 66.69%). The lowest area in 2021 with a percentage of 28.08%)) within the medium deterioration category. As for the third category, high erosion represented the largest area of the region in 2021 with a rate of (68.59%) and the least area in 2011 with a percentage of (32.48%) and represented the severe deterioration category, and the reason for the increase Wind erosion processes in the dry and semi-arid areas are due to the lack of vegetation cover and weak soil construction, as well as the drought years experienced by the region.

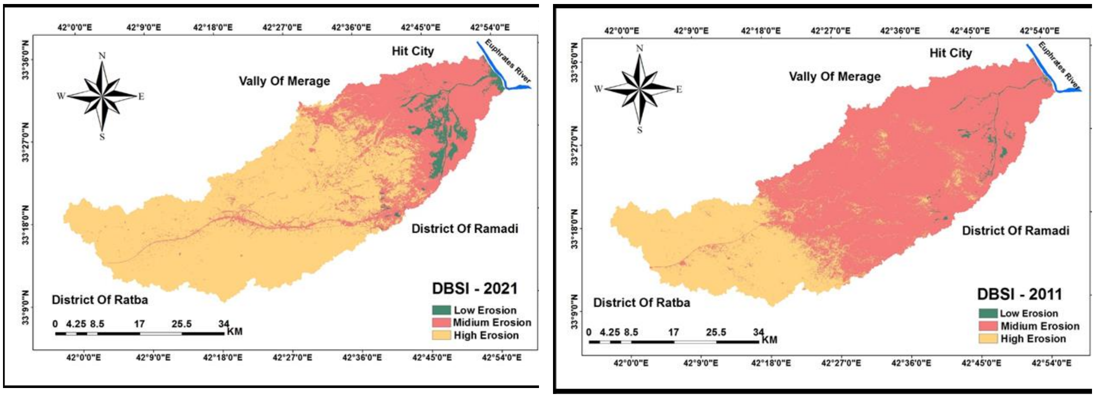
Table 5: DBSI Salinity Index Index for the years 2001 - 2011 – 2021

DBSI values for years		erosion guide indicator	degree of deterioration	Area km2	The ratio%
2001	0.30 - 0.27-	slim stripping	slight deterioration	37.49	1.90
	0.40 - 0.31	Medium stripping	moderate deterioration	699.26	35.47
	0. 50 – 0.41	high stripping	severe deterioration	1234.74	62.63
2011	0.35 - 0.11-	slim stripping	slight deterioration	16.17	0.82
	0.46 - 0.36	Medium stripping	moderate deterioration	1314.88	66.69
	0.54 – 0.47	high stripping	severe deterioration	640.43	32.48
2021	0.08 – 0.26-	slim stripping	slight deterioration	65.55	3.33
	0.15 – 0.09	Medium stripping	moderate deterioration	553.69	28.08
	0.21 – 0.16	high stripping	severe deterioration	1352. 24	68.59

Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Figure 5: DBSI maps of the Wadi Muhammadi Basin for the years 2001 - 2011 – 2021





Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

LDI results

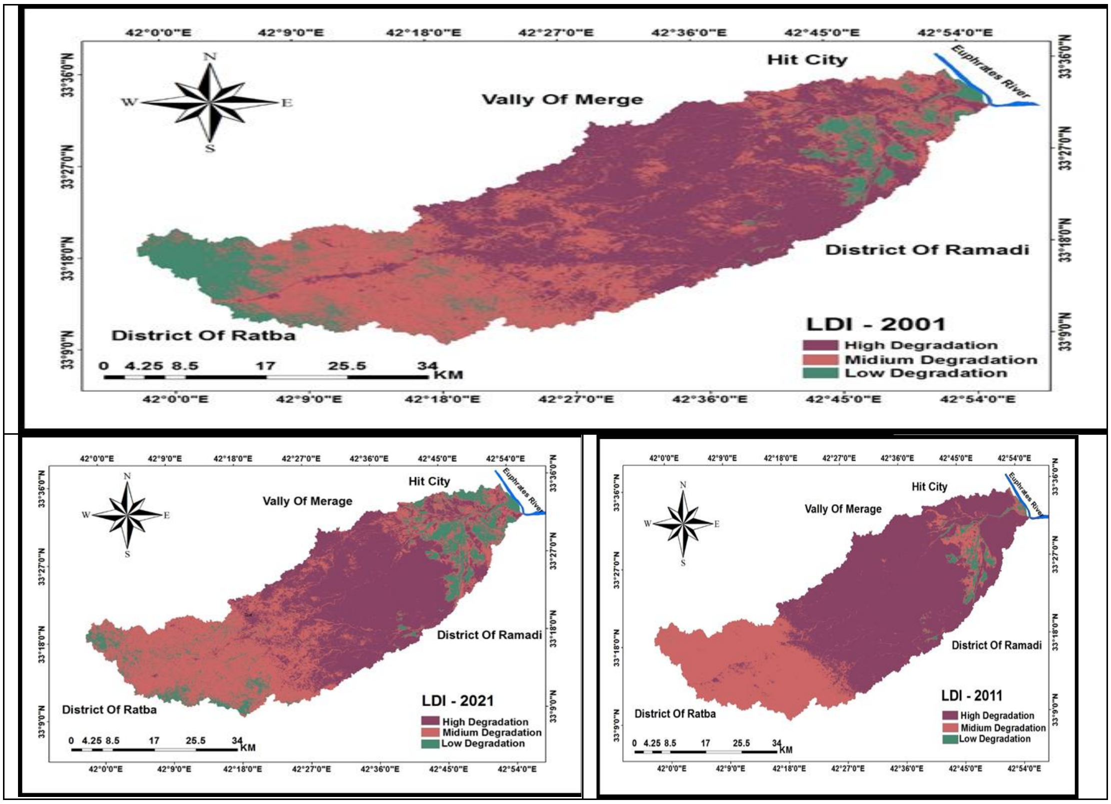
Soil deterioration increases dramatically with the decrease in vegetation cover, which contributes to weak soil construction and cohesion. The study area was classified into three categories according to the indicator (severe deterioration, moderate deterioration, weak deterioration). According to the results of Table 6 and Figure 6, it was found that the first category is severe deterioration. Which is characterized by the absence of vegetation cover, the highest area was recorded in 2011 with a percentage of (62.67%), while the lowest area was in the year 2021 with a rate of (45.39%). In the year 2011 with a percentage of (35.27%), as for the weak deterioration category, it formed the highest area in 2001 with a rate of (12.10%) and the lowest area in 2011 with a percentage of (2.06%). and lively.

Table 6: Salinity Index Index LDI for the years 2001 - 2011 – 2021

LDI values for years		degree of deterioration	Area km2	The ratio%
2001	0.65 – 0.51	severe deterioration	949.93	48.18
	0.68 – 0.66	moderate deterioration	738.001	39.72
	0.79– 0.69	weak deterioration	238.55	12.10
2011	0.62 – 0.51	severe deterioration	1235.47	62.67
	0.67 – 0.63	moderate deterioration	695.38	35.27
	0.77 – 0.68	weak deterioration	40.64	2.06
2021	0.69 – 0.61	severe deterioration	894.96	45.39
	0.71 – 0.70	moderate deterioration	852.42	43.34
	0.76 – 0.72	weak deterioration	222.11	11.27

Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Figure 6: LDI maps of Wadi Muhammadi Basin for the years 2001 - 2011 – 2021



Source: TM&OLI satellite image analysis, 30-meter resolution, Landsat 5&8 satellite, 2001, 2011 and 2021, using Arc GIS 10.8.1 program.

Conclusions and Recommendations

It was concluded by calculating the values of the indicators and determining the degrees of deterioration for the NDVI indicator (slight improvement, mild deterioration, moderate deterioration, and severe deterioration) and the values of the results of the other indicators of the study classified into three categories of deterioration: weak deterioration, moderate deterioration, and severe deterioration. The results showed the possibility of modern technologies to know the nature of land degradation in the studied area by relying on spectral indicators through remote sensing means to assess cases of deterioration. The study recommends using remote sensing techniques to assess the state of land degradation and obtain accurate results and compare between the past and the present.

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