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Environmental Assessment of the Soils of Al-Muqdadiyah District in Diyala Governorate Using Spectral Indicators and Indices

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Abstract

Soil is an important subject as it is a fundamental component of the environment, especially considering the global information revolution and digital technologies, which have provided a realistic view for detecting soil degradation. This study relied on using spectral indices to infer soil quality in the Muqdadiya District of Diyala Governorate. It employed a range of ideas using geographical techniques (Geographic Information Systems and Remote Sensing). The study area covered 478 km², making it the second-largest district in Diyala after the governorate center.

Several indices were used to assess the environmental condition of the study area, including the Bare Soil Index (BI) and the Normalized Difference Salinity Index (NDSI), over two time periods (2010-2023). The results revealed an expansion in the barren land area, which reached 160 km², accounting for 33.6% in 2010, whereas it increased to 292 km², constituting 55.4% of the total area in 2023.

Regarding soil salinity, slightly saline lands covered 20 km² (3% of the total study area) in 2010. By 2023, the index showed an increase in saline lands to 221 km², or 40%, due to various human and natural factors.

Keywords: *Soil, Soil Quality Indicators, Barren Soils Bi, Saline Soils Si.*

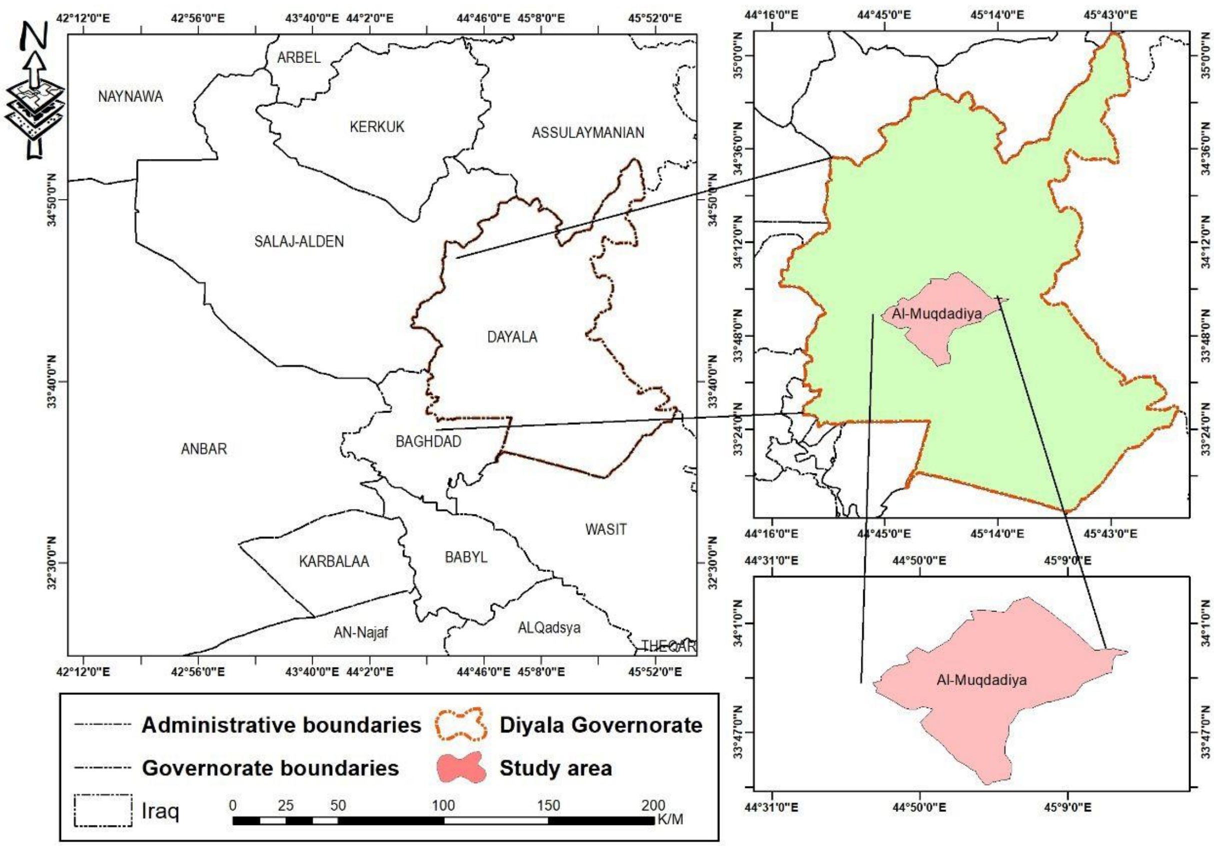
Introduction:

What is the benefit of employing digital data in building models in the form of maps to infer the environmental reality in Al-Muqdadiyah District and thus evaluate it to provide treatments?

The research shows that there is a possibility of employing digital data in building an information base, in the form of conceptual maps, to infer environmental assessment, especially in places that are difficult to reach, and to achieve a degree of accuracy in analysis and interpretation to develop the region’s environment, which supports decision-makers in future plans.

The study area is located in Diyala Governorate, which is one of its districts located to the north of Baladruz District, as it is bordered to the south, to the east by Khanaqin District, and to the northwest by Al-Khalis District and Baqubah District. As for the astronomical aspect, it is located between two latitudes (33.948598 and longitudes 44.9159938).

Map (1): Location of the study area
***Source**: Researcher based on, Republic of Iraq, General Survey Authority, Baghdad, 2007.*

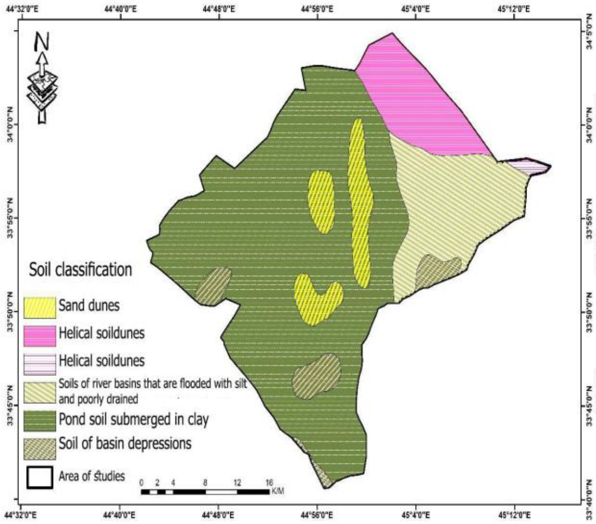


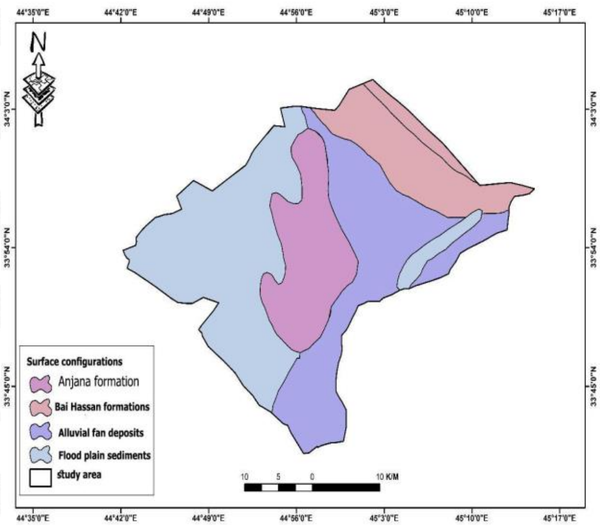
Geological structure is one of the natural factors that shape the landscape. Geological structure refers to the type and condition of rocks, as rocks differ in their degree of hardness and resistance to geomorphological processes, as some are of low hardness and others are hard, in addition to the condition of rocks that determines the degree of response and influence on internal processes represented by torsional and fracture movements and the resulting cracks and joints (Karbal, 1986: 26).

Table (1): Area and percentage of geological formations in the study area

Thickness	**present %**	**Area km^2**	**Hardness**	**characteristics**	**Formation name**	**Age**	**Time**
300-190	28.5	118.3	Hard	Sandstone Mudstone Silverstone	Bai Hassan	Pliocene	Triassic
1200-1300م	4.49	190.9	Very hard	Claystone Sandstone Calcareous sand Sandy-clay-silty	Injana	Miocene	
500-900م	10.31	112.23	Low hardness	Rocks-sand Clay-silt-gravel	Muqdadiyah		
150-200م	56.7	330.2	Hard	Rocks – Sand Clay - Gravel – Gravel	Quaternary sediments (flood plain sediments-marine sediments-human-induced sediments-slope sediments-sabkha sediments	Pliocene	Quaternary
-	100	17617	-	-	-	-	Total

Map (2): Soils in the study area, **Map (3):** Geological formations in the study area





Source*: Researcher based on the Björnck map at a scale of 1:100,000 using Arc Map 10.8.*

The study area was exposed to climatic changes in the Quaternary period represented by rainy periods interspersed with dry periods (Al-Ani, 24: 2011), as it witnessed the development of the dominance of four climatic patterns: cold dry climate, cold humid climate, hot dry climate, and hot humid climate, in the Pleistocene era with successive rainy periods and dry periods (McCullagh, 169: 1986), while in the Holocene, which was characterized by the dry periods currently prevailing (Joudah, 216: 1991), but at the present time, the current climatic conditions in the formation mechanisms indicate that the ancient climatic conditions were more effective and influential, as is evident from the distribution of soil types in the region as shown in the map (3).

The region is characterized by high temperatures during the long summer months, due to the spread of sand within the formations of the region, in addition to the fact that the rock formations are affected by the variation in temperatures and the thermal range, which directly affects the minerals that form the parent rocks, as the heat dries the rocks and disintegrates their components, especially the sand, which has high permeability and porosity. (Hassan and Awad, 2002: 97)

Source: Republic of Iraq, Ministry of Transport, General Authority of Meteorology and Seismic Monitoring.

1. The maximum temperatures at Al-Khalis's station begin to gradually rise from April to reach their highest rates during the summer months, specifically in the months of (June, July, August), as they are considered the hottest months, with the maximum temperatures for the three months reaching (41.02˚C - 43.57˚C - 43.43˚C) respectively at Al-Khalis's station. Temperatures decrease in the winter in the months of (December, January, February) and are considered the coldest months, as those three months recorded (17.98˚C - 15.72˚C - 18.53˚C).
2. The minimum temperatures at Al-Khalis's station recorded the highest rates in the summer months (June, July, August), reaching (22.62˚C - 24.89˚C - 24.30˚C).
3. At Tuz Khurmatu station, it was found that the maximum temperatures gradually rise at the end of March and the beginning of June, i.e. at the beginning of summer, specifically in the months of (June, July, August), as they are considered the hottest months, as the

temperatures for these three months reached (40.55˚C - 41.76˚C - 43.04˚C) and the temperatures decrease in the winter in the months of (December, January, February), as those months recorded (16.55˚C - 14.44˚C - 16.64˚C) Source: Republic of Iraq, Ministry of Transport, General Authority for Meteorology and Seismic Monitoring.

4. As for the minimum temperatures at Tuz Khurmatu station, they recorded the highest rates in the summer months (June, July, August) reaching (25.65˚C - 27.87˚C - 27.30˚C), as there is a large variation in the maximum and minimum temperatures. Source: Republic of Iraq, Ministry of Transport, General Authority for Meteorology and Seismic Monitoring.

This variation leads to the exposed rock surfaces being exposed to mechanical disintegration processes, especially if this variation is accompanied by a lack of precipitation, which is clear in the region. This is what appears on the rock masses due to the presence of irregular cracks in their directions, and this confirms the presence of thermal weathering that occurred due to the shrinkage and expansion that affects the rocks, which works to break the rocks into small sizes that accumulate under the slopes in the region.

As for the amount of precipitation in the region, it is interspersed with long periods of drought, high temperatures, and increased evaporation, which are contributing factors that make the surface of the earth have low moisture content and little vegetation cover, and thus the earth becomes more vulnerable to wind movement and increased movement of sand dunes (Al-Khailani, 2021: 31).

Rainfall begins in October and continues until May with varying amounts. During this period, low-pressure systems become active in Iraq, and the region experiences fluctuations in rainfall from month to month. In Al-Khalis's station, the average rainfall for the months of September, October, and November was recorded as 0.08 mm, 13.40 mm, and 23.48 mm, respectively. Meanwhile, in the Tuz Khurmatu station, the averages for the same months were 0.26 mm, 16.25 mm, and 35.38 mm, respectively. The reason for the low rainfall is due to the infrequent occurrence of frontal low-pressure systems reaching the region during these three months. In winter, rainfall increases in Al-Khalis station during the months of December, January, and February, with amounts reaching 25.73 mm, 31.66 mm, and 28.25 mm, respectively. Similarly, in Tuz Khurmatu, rainfall increases during these months to 45.95 mm, 57.69 mm, and 43.54 mm, respectively. The increase in rainfall is attributed to the higher frequency of low-pressure systems affecting the region.

Spectral Indicators and Clues

First: Bare soil index (BI)

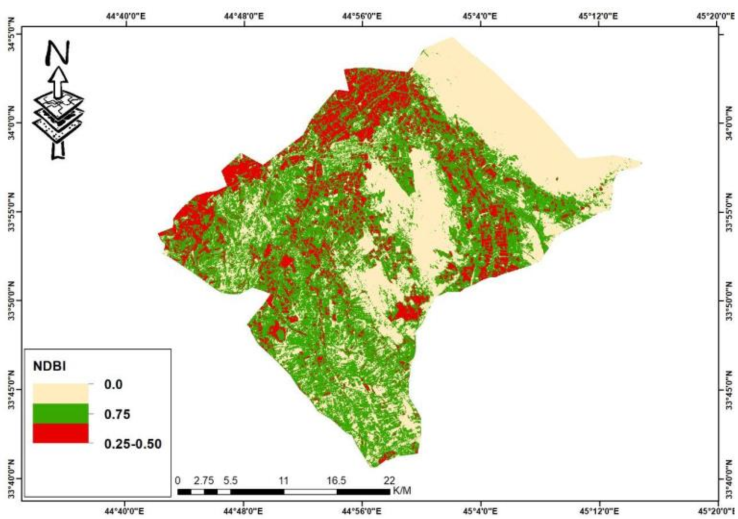
Bare soil refers to the soil and sandy surfaces on the ground that are not covered by any vegetation or ground cover, making them more prone to erosion processes. The Bare Soil Index (BI) was applied in the study area to determine the value of bare soils. BI is a digital indicator that combines spectral bands from infrared, blue, red, and shortwave infrared wavelengths to capture changes in the soil. These spectral bands are used effectively, with the shortwave infrared and red bands utilized to measure the mineral composition in the soil, while blue and near-infrared bands enhance the presence of agricultural and non-agricultural vegetation cover.

Bare lands and vegetation are identified using the BI index (Al-Asadi, 2020: 130). The BI index, derived from Landsat imagery, was used to detect the extent of bare lands, helping in understanding vegetation density and assessing changes in plant health. The values of this index

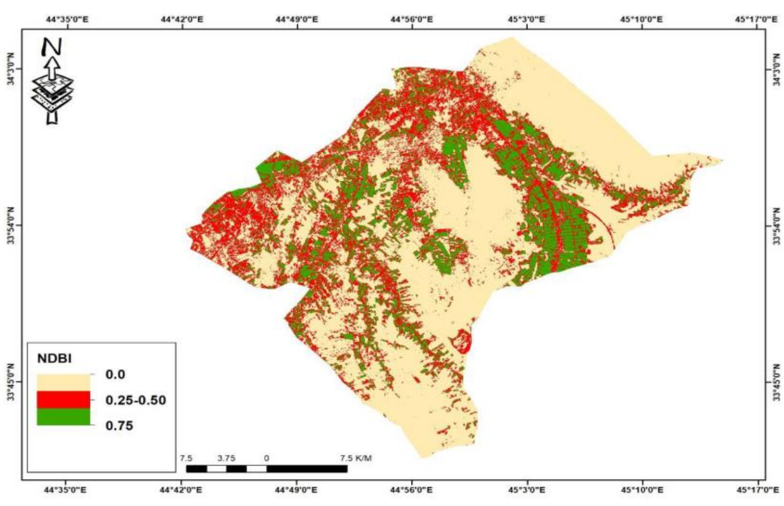
range between (-1) and (+1), with positive values indicating the presence of vegetation that increases with higher values, while negative values signify the absence or reduction of egetation.
The bare soil index is calculated according to the following equation: Rouse, J.W, Haas, R.H., Scheel, J.A., and Deering, D.W. (1974) 'Monitoring Vegetation Systems in the Great Plains with ERTS.' Proceedings, 3rd Earth Resource Technology Satellite (ERTS) Symposium, vol. 1, p. 48-62.
Bi=(Red+swiR)-(Nir+Blue)/(Red+swir) +(NiR+Blue)
- Red: Red band
- Nir: Near-infrared band
- Swir: Shortwave infrared band - Blue: Blue band.

Map (4): Barren soil index (BI) in the study area

***Source**: Researcher based on Landsat visual data dated 4/1/2010 using Arc Map 10.8 software.*



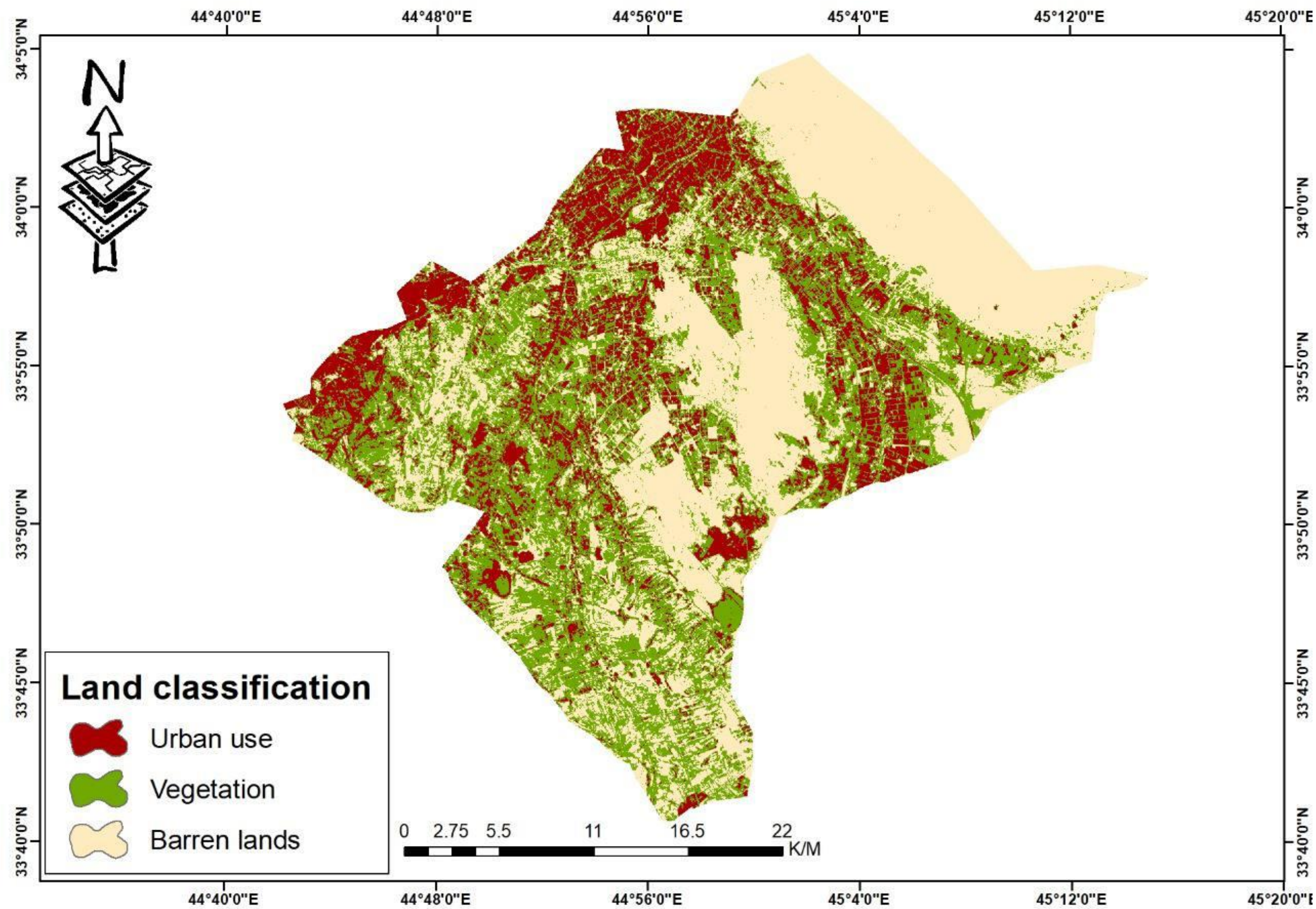
Map (5): Barren soil index (BI) in the study area



***Source**: Researcher's work based on Landsat visual data dated 4/1/2023 using Arc Map 10.8 software.*

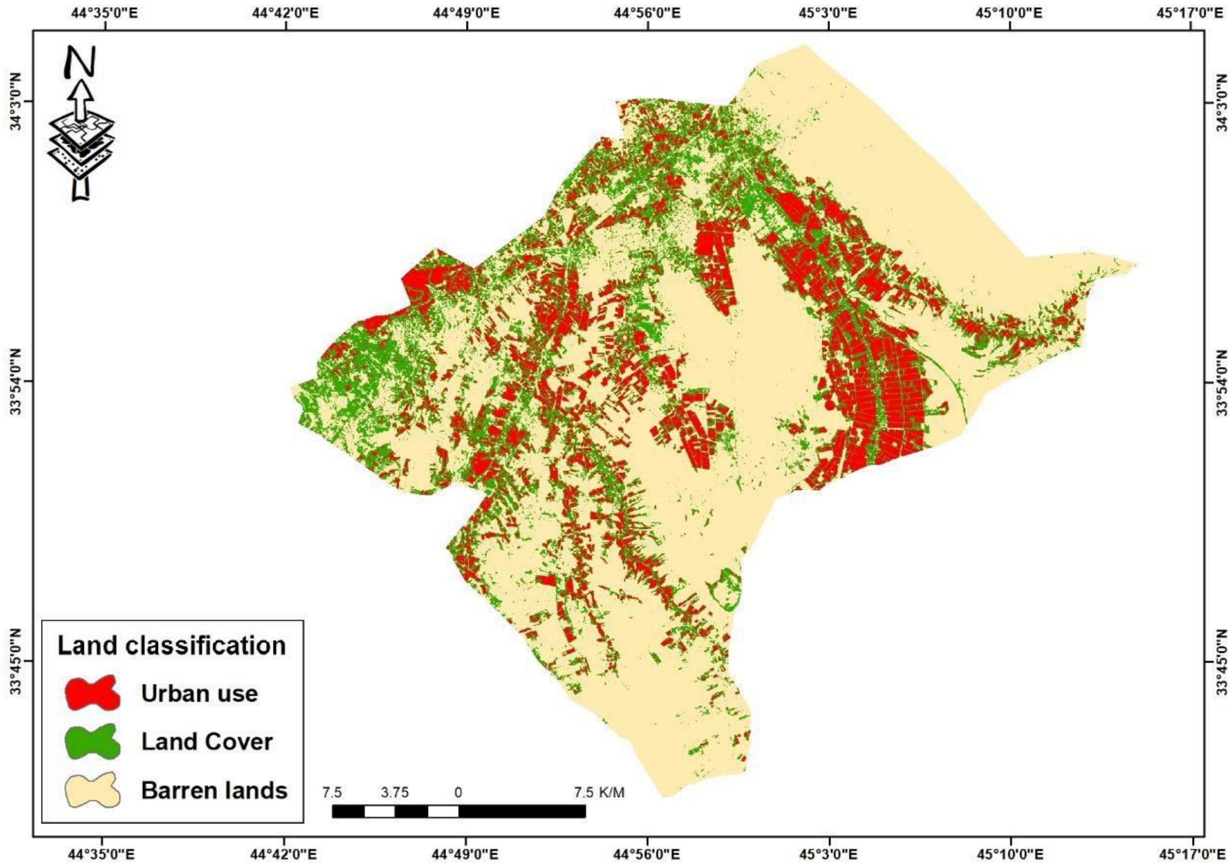
Classification of lands according to the classification of dry lands into three categories based on (Ayad Abdullah Al-Dulaimi, 2016) to show the most important results of spatial modeling to assess the environmental reality of the region and reveal the extent of conformity with the barren soil index, as the lands were reclassified according to the classification directed to the study area.

Map (6): Soil Classification



***Source**: Researcher based on Landsat visual data dated 4/1/2010 using Arc Map 10.8 software.*

Map (7): Soil Classification



Source: *Researcher based on Landsat visual data dated 4/1/2023 using Arc Map 10.8 software.*

Table (2): Area and percentage of barren soil index in the study area in 2010

Categories	**Percentage %**	**Area Km2**
Barren Land	33.6	160
Vegetation Cover	44.2	207
Urban Use	22.2	111
Total	100	478

Source: *Based on data from Map (6).*

Table (3) Area and percentage of barren soil index in the study area in 2023

Percentage %	Area km2	Categories
55.4	292	Barren Land
27.2	98	Vegetation
17.4	87	Urban Use
100	478	Total

***Source**: Based on data from Map (7).*

Table (2) shows that green lands (vegetation cover) cover a large area of the study area, amounting to 207 km2, representing 44.2% of the total area of the area, while the area of barren lands in the study area amounted to 160 km2, representing 33.6% of the total area of the study area. Urban use amounted to an area of 111 km2, representing 22.2%.

As for Map (7) Table (3) for the year 2023 for the soil index, it shows the following:

It was found that green lands (vegetation cover) cover a large area of the study area, amounting to 10,809 km2 and a percentage of 60.2%, while the area of barren lands in the study area amounted to 6,808 km2 and a percentage of 39.8%.

The difference in areas is due to several reasons, including climate extremes, which contribute to the activity of wind erosion processes.

It is evident from this that there is a temporal variation in soil quality, and this is due to several reasons, including the fact that the study area has been subjected to decline and degradation (both natural and human-induced) in recent years due to the nature of declining rainfall and rising temperatures, which affected the type and density of vegetation cover, which in turn affected soil quality and fertility. In addition to poor human management of soil use, the increase in wind erosion rates at Al-Khalis station is due to several reasons, including (the lack of vegetation cover: vegetation resists wind flow, thus reducing wind speed, so the lack of vegetation cover leads to faster wind flow - dryness and fragmentation of the soil - wind speed and strength, as wind speed increases the erosion process). On the human side, military operations in Diyala Governorate contributed to the fragmentation and breakdown of the soil's surface layer, making it more vulnerable to wind erosion and increasing the area of barren lands. Population displacement and urban expansion have also contributed to the increase in barren land areas.

Thus, we conclude that the study area has experienced decline and degradation in recent years due to the nature of declining rainfall and rising temperatures, which affected the type and density of vegetation cover, which in turn impacted soil quality and fertility, in addition to poor human management of soil use.

Normalized Variation Soil Salinity Index (NDSI)

The natural variation index of soil salinity is one of the most important indicators in detecting the natural variation of soil salinity. The values of the salinity index range between (1) and (-1). The closer it is to (1), the lower the percentage of salts in the soil, and the closer it is to (-1), the higher the percentage of salinity. (Shnaishel, 2024: 437).

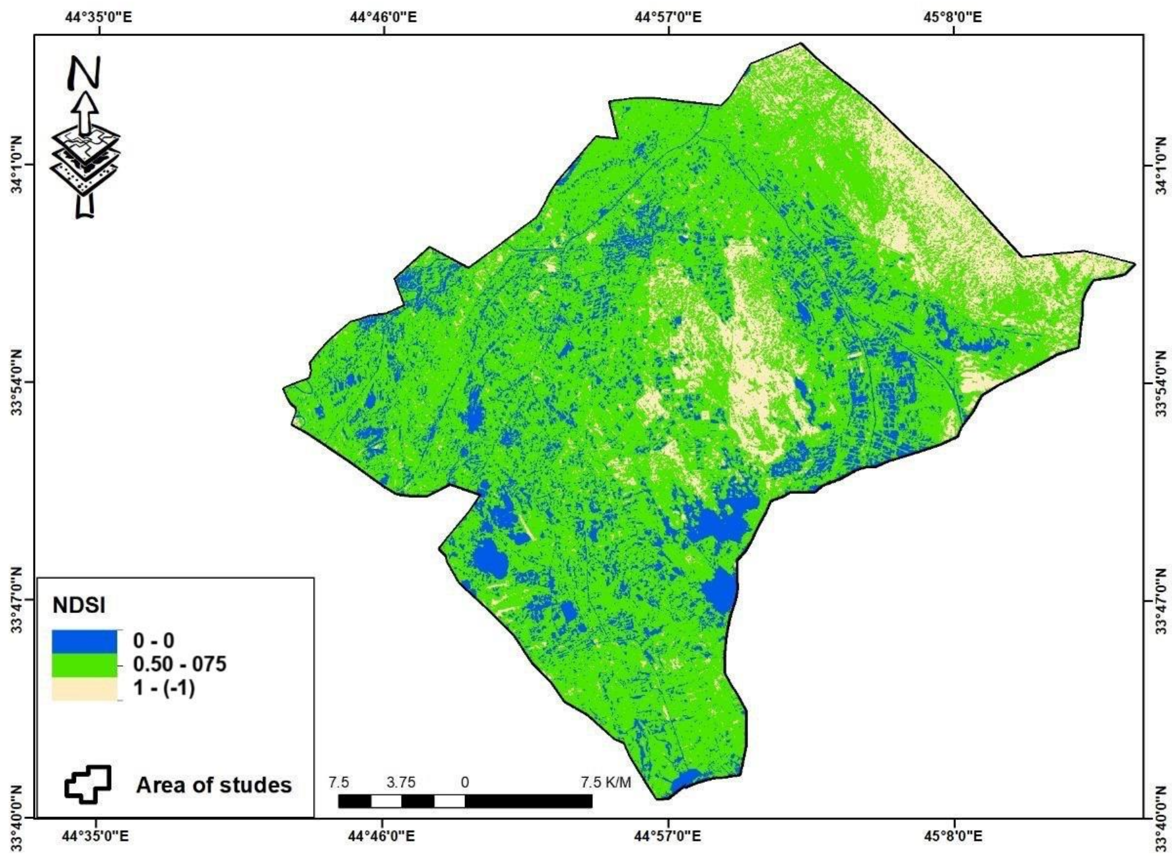
The spectral range of the index in the seventh satellite's visibility for this index ranges between (450-12500) while in the eighth satellite's visibility it ranges from (435-12510).

In Landsat 8, NDSI SWIR_1−SWIR_2/SWIR_1+SWIR_2

SWIRI−SWIRII/SWIRI+SWIRII In Landsat 8

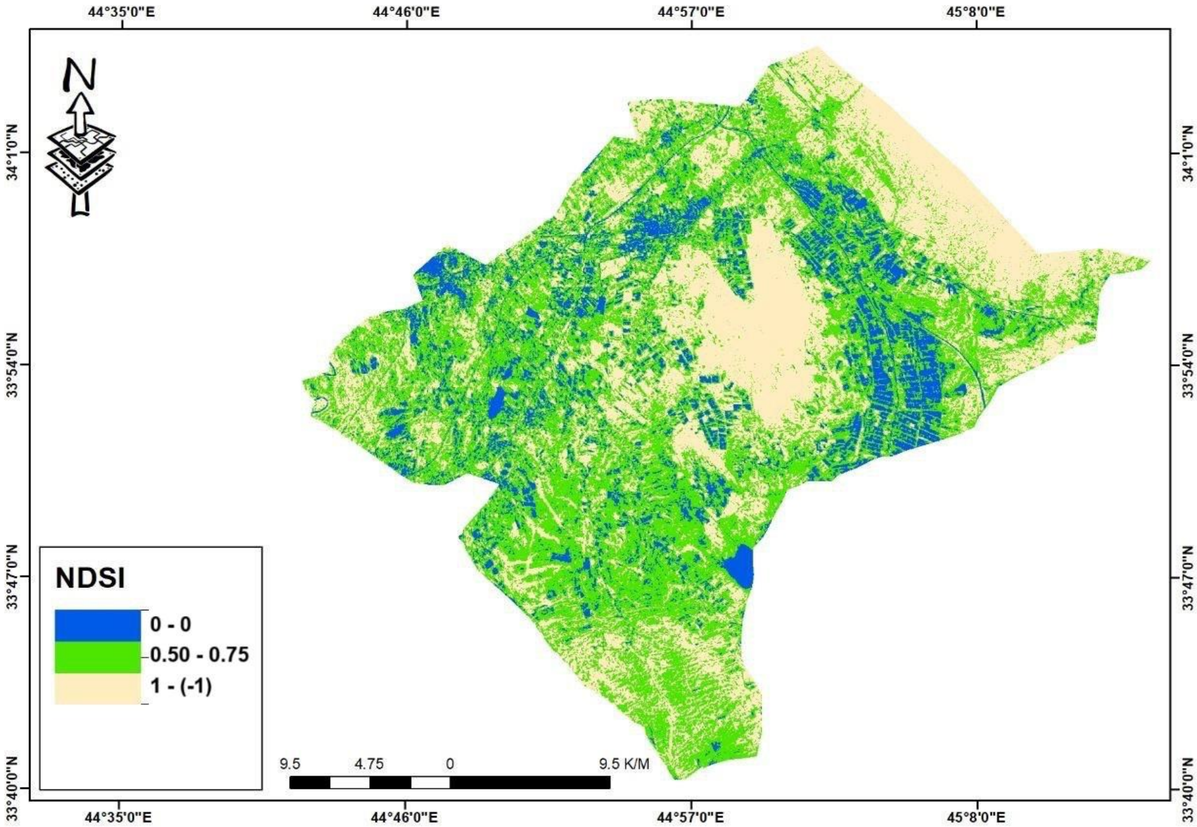
https://www.usgs.gov/search?keywords=EMI

Map (8): Soil Salinity Index (SI) Study Area



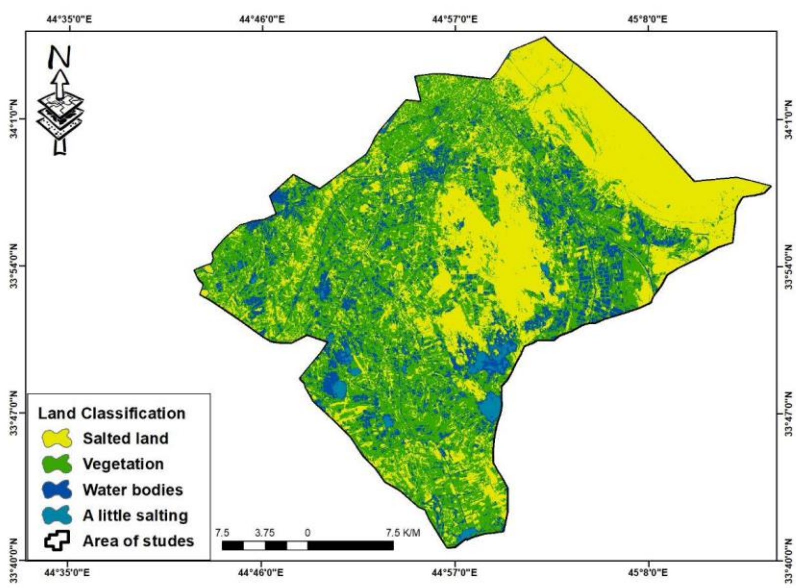
Source: *Researcher based on Landsat visual data dated 4/1/2010 using Arc Map 10.8 software.*

Map (9): Soil Salinity Index (SI) Study Area



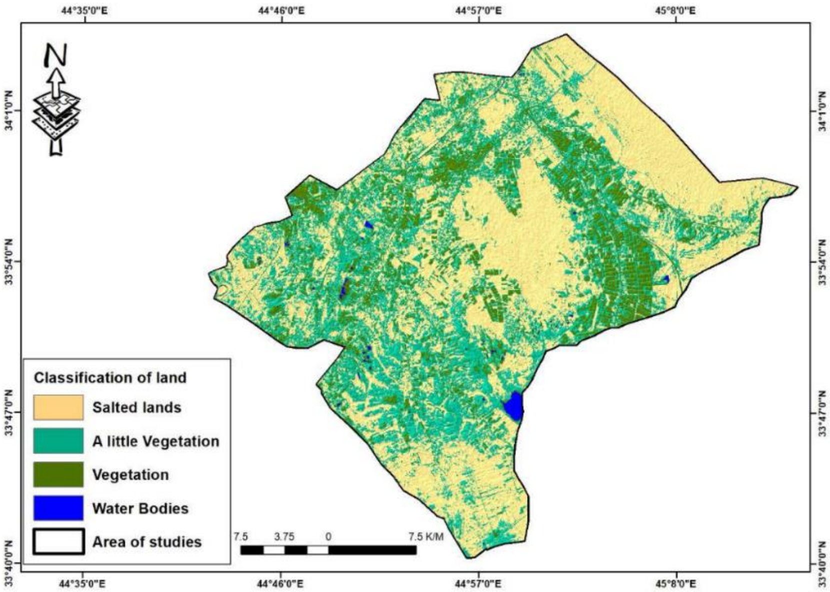
***Source**: Researcher based on Landsat visual data dated 4/1/2023 using Arc Map 10.8 software.*

Map (10) Land cover classification of the study area



Source: Researcher based on Landsat visual data map (8) dated 4/1/2010 using Arc Map 10.8 program.

Map (11): Land cover classification of the study area



***Source**: Researcher based on Landsat visual data map (9) dated 4/1/2010 using Arc Map 10.8 program.*

The lands were classified according to the values available in the index into four sections, based on the classification of lands directed by Ayad Al-Dulaimi in dry lands into four sections:

Table (4): Land classification in the study area in 2010

Categories	**Percentage (%)**	**Area (km²)**
Saline Lands	27.6	160
Low Salinity	3.2	20
Vegetation Cover	44.2	250
Water Bodies	25	48
Total	**100**	**478**

***Source**: Based on data from Map (10)*

Table (5): Classification of the study area lands in the year 2023

Categories	**Percentage (%)**	**Area (km²)**
Saline Lands	30	180
Low Salinity	40	221
Vegetation Cover	26	58
Water Bodies	4	19
Total	**100**	**478**

***Source**: Based on data from Map (11).*

From the analysis of Map (10) and Table (4), the area of saline lands in the study region reached 160 km², accounting for 27.6% of the total area. In contrast, the area of slightly saline lands in the study region amounted to 20 km², representing 3.2% of the total area. The vegetation cover extended over an area of 250 km², making up 44.2%, while water bodies covered 48 km², accounting for 25% of the total area.

As for Map (11) and Table (5) for the year 2023, the following is indicated:

The area of saline lands in the study region reached 180 km², accounting for 30% of the total area. Meanwhile, the area of slightly saline lands in the study region amounted to 221 km², representing 40% of the total area. Vegetation cover extended over an area of 58 km², making up 26%, while water bodies covered 19 km², accounting for 4% of the total area.

From this, we can conclude the following variations: an increase in saline lands, a decrease in green areas, and a reduction in the extent of water bodies.

This problem has several key causes, the most important of which are:

First: Natural Causes, which include:

a. The slope of the alluvial plain, for a distance of more than 650 km, the plain rises only to 91 meters at Samarra and 60 mat Hit, and Baghdad 34 m and Basra 2.40 m, in which its height does not exceed the head of the Arabian Gulf by a few centimeters. (1) Taghlib Jarjis, Applied Geomorphology, Baghdad, Dar Al-Jamiah for Printing, Publishing and Translation, 2002, p. 100.

This is in addition to the lateral slope from the plateau towards the alluvial plain and from the eastern mountains towards the plain. This slope also led to the obstruction of the natural drainage of groundwater and consequently the increase in soil salinity.

b. Climatic Conditions: The high summer temperatures, exceeding 50°C, along with increased hours of daily sunlight, which surpass 14 hours, are accompanied by a significant drop in relative humidity and clear skies. All of this contributes to intense evaporation from the soil and transpiration from plants, resulting in lower surface soil pressure compared to its subsurface. This difference in pressure facilitates the upward movement of subsurface water through capillary action, leading to continuous soil salinization.

c. Climate Warming: Primarily caused by the burning of oil, gas, and coal, climate warming has led to a persistent and severe drought in Iraq in recent years.

d. The Turkish "GAP" Project: The Southeastern Anatolia Project (GAP), which includes the Ilisu Dam, poses a threat as it prevents 36% of the Tigris River's water from entering

Iraq. This project is a significant risk to the entire region and is a major contributor to drought conditions in Iraq.

e. Soil Properties: The sedimentary soil in the region contains a high percentage of salt, particularly when reservoirs are drained. These salts migrate to the soil either through irrigation or seepage, further increasing soil salinity.

Second: Human factors:

a. The unregulated irrigation system, especially in the summer, coupled with the expansion of summer agriculture and excessive irrigation.
b. Leaving some agricultural lands uncultivated for one reason or another.
c. Not adopting the agricultural rotation system.
d. The military operations that took place in the district because of the ISIS war 2014-2017 led to the destruction of agricultural lands and the displacement of residents from the area

Processors:

a. Establishing main and field drains and connecting them to the general drain.
b. Adopting the agricultural rotation system where crops that help reduce soil salinity are introduced such as barley and clover.
c. Regulating irrigation systems using advanced irrigation techniques such as drip and sprinkler and lining irrigation canals to reduce water losses and seepage.
d. Monitoring irrigation and drainage systems and maintaining their suitability for operation throughout the year and cleaning them from plants that hinder their operation such as reeds, papyrus and senna.

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