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Spectral Indices of Selected Physical Properties Influencing Dust Storms in Southern Iraq: A Case Study of Al-Kutaia Region

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Abstract:
The research employed remote sensing techniques to monitor environmental degradation in the study area by analyzing indicators ((NDVI, SI, TCI, BSI), and the results revealed a sharp seasonal variation; the vegetation cover recorded a surge in its “dense” category in the summer at a rate of (33.2%) as a result of irrigated agriculture, which is countered by an alarming decline in water bodies to (2.5%). The study also identified the dominance of “low salinity” at a rate of (65.1%) in August due to severe evaporation, coinciding with the expansion of the medium erosion area to include (67.9%) of the area, which turned the region into an active hotspot for the emergence of dust storms.

Keywords: Spectral indicatorsSpectral Indices; Physical Properties; Dust Storms

First: Introduction:

The study of spectral indicators of natural characteristics is a cornerstone in studies concerned with understanding and analyzing the role of the local environment of the region and its relationship to the emergence of dust storms. Remote sensing techniques are an important and essential pivotal tool in analyzing environmental dynamics and classifying land cover with high accuracy, especially in arid desert regions that face severe climatic challenges. This research aims to assess the spatial and temporal variation of vegetation cover indicators and measure salinity, aridity and barren soil in the study area. Studying these indicators constitutes an important step in analyzing the causes of dust storms and ways to treat them and identify the requirements necessary to confront them.

Second: The research problem:

The problem addressed in this study can be summarized as follows:

1- What is meant by spectral indicators?

2- Is there a relationship between natural characteristics and dust storms in the study area?

Third: Research hypothesis:

1- It is a technology that uses remote sensing (Remote Sensing) to measure the relationship between the natural characteristics of the area and the problem of study.

2- The study assumes a direct relationship between natural characteristics and dust storms in the study area.

Fourth: Research objectives:

1- The study of the spectral indicators of natural factors in the study area aims to analyze the role of these factors and their relationship in the emergence of dust storms in the region and the extent of their influence.

2- This study seeks to achieve a true understanding of the impact of the region’s natural environment, the extent to which it is affected by climate change, and the reflection of these spatial and temporal changes in the formation of the dust storm phenomenon.

Fifth: Scope of the research:

The study's boundaries represent the general framework that surrounds it, as this framework constitutes the researcher's field of work and the limits of their work, helping them achieve the best results. It consists of:

1- Spatial boundaries of the research:

The geographical boundaries of the study were defined as the Al-Kutay'ah region and the areas under its influence, which overlap with three governorates: Dhi Qar, Al-Muthanna, and Al-Diwaniyah. Its total area is 12,448.03 km², although there are no accurate population statistics. Astronomically, the study area is located at longitude 45°46'15"E and latitude 31°45'31'0"E.(North).[1)]See map (1).

2- Time limits of the research:

The time frame of the study represents the years that were used to measure and analyze the data of the study problem, and they range between the years (1994-2025).

Sixth: Research concepts:

1- Spectral indicators (Spectral Indices):

Spectral indices are defined as algorithms or mathematical equations (often based on ratio calculations or addition and subtraction operations) applied to spectral reflectance values recorded in different spectral bands.(Bands) for satellite imagery, and its main purpose is to highlight specific environmental and geographical phenomena on the Earth's surface for accurate identification (such as assessing the health of vegetation cover, monitoring water bodies, or identifying urban expansion) as well as isolating and mitigating the effect of background factors that may distort the image (such as soil color, variations in lighting and angles of incidence of sunlight, and topographic shadows).[2)]

2- Natural factors (Physical Properties:

It is the set of physical and biological characteristics and elements that naturally and independently constitute the terrestrial environment, without any human intervention, creation, or direction. These factors represent the "ecological stage" on which living organisms interact. They are the primary determinant that directs patterns of human settlement, density, and spatial distribution, in addition to imposing restrictions or granting opportunities that determine the nature of their economic activity (agricultural, industrial, and commercial) and their urban planning. Among the most important natural factors are the six basic factors: location, topography, geological structure, climate, soil, and water resources.[3)]

3- Dust storms:

The word "dust" suggests very fine soil particles suspended in the air. A "dust storm" is defined as: strong winds carrying enormous numbers of sand and mud particles, with a diameter ranging from (0.002 - 500) microns, suspended in the air at a height of approximately (1000 - 3000) meters. The concentration of suspended particles reaches thousands of particles per (2 cm2). The wind speed at which dust storms occur ranges from (37 - 60 km/h). Dust storms are associated with other weather phenomena that are similar in terms of the size of the particles stirred up in each and the degree of horizontal visibility obstruction, such as suspended dust, rising dust, and haze.[4]

(1) Field study for the year (2024- 2026).

(2)Asil Jassim Mohammed AwashAnd others,Hydrological spectral indicators of Iraq using remote sensing afterInformation systemsGeographyResearch (published)Journal of the College of Education (Volume 56, Issue 2)2024, p. 383.

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[4]Jawaher Mufreh Mar’i Al-Qahtani, Sand and Dust Storms in Southern Saudi Arabia, Master’s Thesis (Unpublished), College of Humanities, King Khalid University, Saudi Arabia, 2020, p. 82.

Seventh: Spectral indicators of some natural features in the study area:

The natural characteristics of the study area are significant factors in the formation of dust storms, given the harsh climatic conditions it experiences. Since this study relies primarily on the analysis of digital models of the region, a set of spectral indicators for certain natural characteristics that can combine within specific temporal and spatial boundaries to form dust storms was analyzed. Two time periods were used to analyze the study area: late spring and summer, specifically April and August. April represents the peak of dust storm occurrence in the study area, while August represents the peak of harsh climatic conditions, including drought, high temperatures, reduced vegetation cover, and a sharp decline in soil moisture, in addition to a severe decrease in water resources. These conditions create climatic conditions conducive to the formation of dust and storms in the region. The analysis of satellite imagery, which relies on spectral indicators with precise scientific readings, combined with a study of the spatial reality, provides a clear picture of the natural characteristics the region experiences over time. These indicators include:

1- Vegetation cover variation index (NDVI):

This index represents the degree of variation in vegetation cover and is considered one of the important indicators that form the cornerstone in the study of land cover classifications that rely on remote sensing in any region. It reflects, through spectral rays, the characteristics of the studied region and classifies it into classifications that are distinguished by unique characteristics according to approved scientific standards, as well as through a simple equation that links the reflection of red rays and near-infrared rays. The analysis of satellite imagery of the study region showed the index (The NDVI for the month of April shows that the land cover classifications of the study area vary clearly, as shown in Table (1) and Map (2). The study showed that the area of land with light vegetation cover amounted to (2965.47 km2), with a percentage of (23.9%), while the area of land with medium vegetation cover amounted to (7614.75 km2), with a percentage of (61.1%), which is the largest area in the study area. The area of dense vegetation cover amounted to (91.72), with a percentage of (0.8%), which is a remarkable percentage that clearly shows the large absence of this classification in the region and explains its transformation into a major source of dust storms at this time in particular. As for the areas where there is no vegetation cover, their area amounted to (1241.29 km2), with a percentage of (10.0%). The area of water bodies in the region amounted to (534.8 km2), with a percentage of (4.2%). Thus, it appears that the region, according to this indicator, suffers from a decrease in the percentage of water bodies at this time of year.

Table (1) Land cover classifications according to the index (NDVI) for the month of April of the year (2024) for the study area.

%	Area km2	Classification	T
23.9	2965.47	light plant cover	1
61.1	7614.75	Medium vegetation cover	2
0.8	91.72	dense vegetation cover	3
10.0	1241.29	Lack of vegetation	4
4.2	534.8	Water bodies	5
100	12448.03	the total	

Source: Researcher's work based on: satellite imagery (Landsat 8) for 2024.

According to the same indicator and through the analysis of the satellite image for the month of (August), it appears that the classifications of vegetation cover in the study area have increased in intensity of their variation with the peak of summer. Table (2) and map (3) show that the area of land with light vegetation cover decreased to (16.02 km2), with a percentage of (0.2%), while the area of land with medium vegetation cover decreased to (6659.33 km2), with a percentage of (53.4%), while the area of dense vegetation cover increased significantly to (4137.77 km2), with a percentage of (33.2%) at this time. This increase may be explained by the activity of summer agriculture in specific parts of the study area. As for the areas where there is no vegetation cover, their area reached (1320.79 km2), with a percentage of (10.7%), while the area of water bodies in the region decreased to (314.12 km2), with a percentage of (2.5%) due to the extreme rise in temperatures and the absence of rain.

Table (2) Land cover classifications according to the index (NDVI) for the month of August of the year (2024) for the study area.

%	Area km2	Classification	T
0.2	16.02	light plant cover	1
53.4	6659.33	Medium vegetation cover	2
33.2	4137.77	dense vegetation cover	3
10.7	1320.79	Lack of vegetation	4
2.5	314.12	Water bodies	5
100	12448.03	the total	

Source: Researcher's work based on: satellite imagery (Landsat 8) for 2024.

2- Soil salinity measurement index (SI):

This index classifies saline lands by analyzing the values of the reflected spectral radiation of the study area via remote sensing, and by analyzing satellite imagery (Land sat 8) In April of the year (2024), the lands are classified according to their salinity levels. Looking at Table (3) and Map (4), it appears that the area of lands with very low salinity amounted to (534.8 km2) and a percentage of (4.8%), and the area of lands with low salinity amounted to (1241.29 km2), while the area of lands with medium salinity amounted to (2965.47 km2) and a percentage of (23.6%), while the area of lands with high salinity amounted to (7614.75 km2) and a percentage of (61.1%). These areas constitute the largest areas in the study area, which explains their agricultural poverty and their transformation into barren areas. The area of lands with very high salinity amounted to (91.72 km2) and a percentage of (0.7%).

Table (3) Soil salinity classifications according to the index (SI) for the month of April of the year (2024) for the study area.

%	Area km2	Classification	T
4.8	534.8	Lands with very low salinity	1
9.8	1241.29	Low salinity soils	2
23.6	2965.47	Medium-salinity soils	3
61.1	7614.75	High salinity lands	4
0.7	91.72	Lands with very high salinity	5
100	12448.03	the total	

Source: Researcher's work based on: satellite imagery (Landsat 8) for 2024.

Through analysis of the saline land classification index ((SI) For the study area, the amount of variation in the classifications of the salinity index for the region increases. Looking at Table (4) and Map (5), it appears that the area of very low salinity lands decreased to (18.62 km2) and a percentage of (0.2%), while the area of slightly low salinity lands increased very significantly to reach (8097.6 km2) and a percentage of (65.1%),

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which constitutes the largest area for the classifications of this index at this time of year. As for the medium salinity lands, they reached (2966.6 km2) and a percentage of (23.8%), while the area of high salinity lands reached (1088.47 km2) and a percentage of (8.7%). The area of very high salinity lands increased to (276.74 km2) and a percentage of (2.2%). It is noted that the area of saline lands for the region increases in the summer season in general, and this may be attributed to the large increase in temperatures, increased severity of drought, and decrease in soil moisture.

Table (4) Soil salinity classifications according to the index (SI) for the month of (August) of the year (2024) for the study area.

%	Area km2	Classification	T
0.2	18.62	Lands with very low salinity	1
65.1	8097.6	Low salinity soils	2
23.8	2966.6	Medium-salinity soils	3
8.7	1088.47	High salinity lands	4
2.2	276.74	Lands with very high salinity	5
100	12448.03	the total	

The researcher's work is based on: satellite imagery of the moon (Landsat 8) for 2024.

3- Drought status index (TCI):

This indicator measures the spatial and temporal variation of drought levels through remote sensing. It is an important measure for understanding the environmental conditions of the study area. Analysis of Table (5) and Map (6) shows that the drought status index for the month of (April) in the study area is distributed according to the degree of drought. The lands with very severe drought occupy an area of (0.03 km2) and a percentage close to (0.0%). The lands with severe drought occupy an area of (3326.18 km2) and a percentage of (26.7%). The areas with moderate drought reached an area of (4851.5 km2) and a percentage of (38.9%), which represents the widest classification of this indicator in the region. The area of the areas with mild drought reached an area of (2999.28 km2) and a percentage of (24.2%). The areas where there is no drought occupy an area of (1271.04 km2) and a percentage of (10.2%).

Table (5) Classification of drought degrees according to the (TCI) for the month of (April) in the study area for the year (2024).

%	Area km2	Classification	T
0.00	0.03	Extremely severe drought	1
26.7	3326.18	severe dryness	2
38.9	4851.5	moderate drought	3
24.2	2999.28	mild dryness	4
10.2	1271.04	There is no drought	5
100	12448.03	the total	

Source: Researcher's work based on: Satellite imagery of the moon (Land sat 8) for the year (2024).

To note the relative variation in drought levels according to the same index, it appears that the severity of drought levels increased in August of the year (2024). Analysis of Table (6) and Map (7) shows that the drought status index for the study area varies steadily, as the area of land with very severe drought decreased to (0.01 km2) with a percentage approaching (0.0%), while the area of land with severe drought increased to (3246.1 km2) with a percentage of (26.1%). The area of moderate drought increased significantly to reach (5123.02 km2) with a percentage of (41.2%), and thus it continues to lead in drought levels according to this index in the region. The area of areas with mild drought increased to (3366.35 km2) with a percentage of (27.0%), while the area of areas where there is no drought decreased to (712.46 km2) with a percentage of (5.7%).

Table (6) Classification of drought degrees according to the (TCI) for the month of (August) in the study area for the year (2024).

%	Area km2	Classification	T
0.00	0.1	Extremely severe drought	1
26.1	3246.1	severe dryness	2
41.2	5123.02	moderate drought	3
27.0	3366.35	mild dryness	4
5.7	712.46	There is no drought	5
100	12448.03	the total	

Source: Researcher's work based on: Satellite imagery of the moon (Landsat 8) for the year (2024).

4- Barren soil index ((BSI):

It is a spectral index used in remote sensing to distinguish areas with exposed (barren) soil with high accuracy from vegetation cover, water bodies and urban areas, and to distinguish areas most at risk of erosion. Looking at Table (7) and Map (8), the classification of the scores of this index for the month of (April) of the year (2024) in the study area is distributed as follows: lands with high erosion, which amounted to (3508.74 km2) and a percentage of (28.2%), areas with low erosion, which amounted to (885.69 km2) and a percentage of (7.1%), while lands with moderate erosion amounted to (1503.76 km2) and a percentage of (12.1%), while the area of areas not affected by erosion amounted to (6176.76 km2) and a percentage of (49.7%), and the area of water bodies in the region amounted to (373.08 km2) and a percentage of (2.9%).

Table (7) Classification of erosion degrees according to the index (BSI) for the month of (April) in the study area for the year (2024).

%	Area km2	Classification	T
28.2	3508.74	Highly eroded lands	1
7.1	885.69	Lands with little erosion	2
12.1	1503.76	moderately eroded lands	3
49.7	6176.76	Lands unaffected by erosion	4
2.9	373.08	Water bodies	5
100	12448.03	the total	

Source: Researcher's work based on: Satellite imagery of the moon (Landsat 8) for the year (2024).

Map (8) Classification of the Barren Soil Index (BSI) for the month of (April) in the study area for the year (2024).

Source: Researcher's work based on the program (Arc map 10.8) and the satellite imagery of the moon (Landsat 8) for the year (2025).

Since erosion rates are affected by seasonal climatic conditions, and considering Table (8) and Map (9), the classification of the scores of this indicator for the month of (August) of the year (2024) in the study area is distributed as follows: the area of lands with high erosion decreases very significantly to reach (0.16 km2) and a percentage approaching (0.00%), while the areas with low erosion have increased significantly to reach (2880.63 km2) and a percentage of (23.2%), and the area of lands with moderate erosion has increased very significantly and clearly to reach (8456 km2) and a percentage of (67.9%), and the area of areas not affected by erosion decreased to (835.1 km2) and a percentage of (6.7%), and the area of water bodies in the region decreased slightly to reach (276.14 km2) and a percentage of (2.2%).

Table (8) Classification of erosion degrees according to the index (BSI) for the month of (August) in the study area for the year (2024).

%	Area km2	Classification	T
0.00	0.16	Highly eroded lands	1
23.2	2880.63	Lands with little erosion	2
67.9	8456	moderately eroded lands	3
6.7	835.1	Lands unaffected by erosion	4
2.2	276.14	Water bodies	5
100	12448.03	the total	

Source: Researcher's work based on: Satellite imagery of the moon (Landsat 8) for the year (2024).

Conclusions and recommendations:

- **Conclusions:**

1- The expansion of the (drought) area intensified the indicator(TCI) stated that the region is experiencing a “drought” condition, with the percentage of drought areas ranging from 10.2% in April to 5.7% in August. The most important point here is that general drought constitutes the vast majority (more than 40%), which means that it is a “dry” region that is highly affected by climate change.
2- The relationship between salinity levels and drought and temperature, as revealed by the index(SI) due to a severe decrease in humidity in the summer; this contributed to an increase in evaporation rates, as salinity dominated as a result, especially in August, by 65.1%, which made the region fall within the high salinity zones.
3- An indicator appears(NDVI) The proportions of vegetation cover in the region varied, and August witnessed a surge in “dense” cover (from 0.8% to 33.2%). This clearly indicates the total dependence on summer irrigated agriculture, while the rain-fed agriculture pattern disappears due to the nature of the desert environment, which makes most of the region’s area outside the agricultural reclamation plan.
4- Wind erosion and dust, as measured by the index ((BSI) We note a dangerous shift in August, as the areas exposed to moderate erosion jumped to include 67.9% of the area, clearly indicating that this region has become a major source of dust storms, as a result of soil disintegration, dryness and the absence of vegetation cover in most of the area.
5- Decrease in surface water resources. The study results showed a significant decrease in water bodies (from 4.2% to 2.5% according to the vegetation cover index), indicating a large water deficit in the region that contributes to the region’s dryness and constitutes an important factor in the emergence of dust storms.

- **Suggestions:**

1- Adopting smart irrigation technologies: This technology is an effective step to reduce water waste and reduce the rise in the level of saline groundwater, especially in areas that are actively engaged in agriculture, such as drip irrigation, sprinkler irrigation, and the use of modern and innovative irrigation methods.
2- Creating green belts: Focusing on planting windbreaks that are appropriate to the climate, salinity and aridity characteristics in areas that have recorded "high erosion" and "severe aridity" and are classified as a major source of dust storms.
3- Biological control of desertification and soil salinity: Expanding saline agriculture (cultivating plants resistant to salinity and drought): by investing in the salinity that is abundant in large areas in cultivating fodder or artificial grasses that are resistant to salinity.
4- Improving soil properties: Adding organic amendments improves the soil's ability to cool with moisture, which increases its resistance to disintegration and its suitability for plant growth.
5- Early warning and continuous monitoring system: Establishing multiple observatories in different locations in the region and relying on remote sensing (on a monthly basis, not just seasonally) to monitor and follow up on “drought and desertification hotspots” and to intervene quickly before they turn into sources of dust storms, as well as the need to build an integrated spatial database of all the natural indicators of the region, in addition to identifying areas nominated for development and the possibility of agriculture in order to determine agricultural support mechanisms for the most effective areas.
6- Water improvement: Investing in rainfall through the use of water harvesting techniques and the construction of small earth dams or underground reservoirs in areas with “severe drought” to utilize the main spring rainwater for the summer drought.

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