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Studying the Environmental Changes Using Remote Sensing and GIS

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Abstract:

The research aims to monitor environmental changes and study the state of desertification in the northeastern part of the Al-Najaf province, Iraq. The study area suffers from desertification and drought phenomena. Remote sensing systems "RS" and geographic information systems "GIS" are essential for monitoring environmental changes because they provide Earth observation satellites that contribute to detecting environmental changes. Two Sentinel 2 images were acquired on December 26, 2015, and November 29, 2021. The images were combined and used for indices calculations. Normalized vegetation difference index "NDVI," Normalized difference index "NDWI," soil exposure index "BSI," and Normalized difference index "NDBI." The results showed that the extent of desertification in the study area began to increase during the study period. Also, the results of change detection showed that the study area became very dry, especially in the western part, suffering from dunes, barren land, and a lack of water sources, especially in the western part of the study area.

Keywords: Environment Changes, desertification, remote sensing, Sentinel 2.

دراسة التغيرات البيئية باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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الخلاصة

يهدف هذا البحث إلى رصد التغيرات البيئية ودراسة حالة التصحر في الجزء الشمالي الشرقي من محافظة النجف. تعاني منطقة الدراسة من ظاهرة التصحر والجفاف، وتعتبر تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية من التقنيات الهامة لرصد التغيرات البيئية لأنها توفر أقمار صناعية تراقب الأرض والتي تسهم في الكشف عن التغيرات البيئية. تم الحصول على صورتين بتاريخ 26 ديسمبر 2015، 29 نوفمبر 2021. تم دمج الصور واستخدامها لحساب مؤشرات البحث. وفي هذه الدراسة، استخدمت مؤشرات الاستشعار عن بعد: مؤشر فرق الغطاء النباتي الطبيعي ومؤشر فرق الماء الطبيعي ومؤشر التربة العارية ومؤشر اختلاف المناطق الحضرية، أظهرت نتائج هذه الدراسة أن مدى التصحر في منطقة الدراسة بدأ بالزيادة خلال فترة الدراسة كما أظهرت نتائج كشف التغيير أن منطقة الدراسة أصبحت جافة للغاية خاصة في الجزء الغربي، وتعاني من الكثبان الرملية والأراضي الجرداء ونقصان الموارد المائية خاصة في الجزء الغربي من منطقة الدراسة

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1. INTRODUCTION

Desertification and environmental changes have become critical global issues in Iraq. Therefore, it is crucial to identify the damaged land dunes and desertification. People, animals, and plants are all affected by the environment, so in the last few decades, changes in human life have caused several environmental problems to worsen; one of these issues is desertification [1].

Desertification has defined as the loss of current or potential production of the land as a result of natural or artificial causes. Also, it is referred to as land degradation in arid, semi-arid, and dry subhumid environments [2]. Iraq is becoming drier because countries upstream are taking away surface water, and rain is getting less, especially in the southern and central parts of the country. Many works have been done to determine causes and effects [3]. Digital change detection is the process of using co-registered multi-temporal remote sensing data to figure out or/and describe changes in land use and land cover. Using RS data to find changes is based on the idea that the process can find changes between two or more dates that are not typical of how the environment changes over time. The change detection process incorporates finding variations in the phenomenon or the state of an object by observing periodically [4]. It means being able to measure the effects of time with the help of multitemporal datasets. Accurate and updated information about changes in land cover was needed to understand and measure the effects of changes on the environment [5]; remote sensing could detect changes, and obtaining information from satellite data necessitates effective and automated change detection techniques [6]. Researchers utilized RS and GIS to study environmental change detection, drought mapping, desertification assessment, and monitoring. Several types of research were conducted to determine how RS could be used to track the spread of desertification, including [6] Hassan's work concentrated on using RS and GIS to find signs of desertification in the Makhmour district.

The researcher used climatic data from DEM, Landsat TM, and ETM⁺ (1988-2016). The results revealed a reduction in vegetation cover, especially in the southern and central regions, observing the expansion of the vegetative and agricultural cover in 1998 and the slow fall in the following years. Studying vegetation and agriculture also helped create a database and maps on the state of desertification and its spread in 2016. Thematic maps were used to calculate Normalized Difference Vegetation Index "NDVI," Normalized Difference Water Index "NDWI," Salinity Index "SI," and Eolin Mapping Index using Landsat (TM, ETM +, and OLI) for 1989, 2002, and 2015 respectively; allowing the evaluation of desertification-sensitive environmental zones of Maysan Province, where population statistics, climate factors, field surveys, and all thematic maps have been connected with GIS environments [7]. The findings showed that the north and west of the research region were affected or very vulnerable to desertification due to the presence of salinity and dunes, dried wetlands, low water revenues due to natural and human sources, and a lack of rainfall. Being closer to the city center, the desertification phenomenon is less than in other locations due to increased rainfall and abundant foliage [7]. This research aims to measure and monitor the desertification of Iraq's central area using RS and GIS. The Crust Index "CI" and NDVI have been performed on two (Landsat ETM + and OLI) satellite images during 1990-2019. The results showed that whereas the entire area of vegetation cover was 2620 km² in 1990, it substantially reduced to 764 km² in 2019, representing 34.8% and 10.2 %, respectively.

Additionally, the statistics showed that dunes spanned 767 km² in 1990 and increased to 1723 km² in 2019, with rates of 10.2 % and 22.9 %, respectively [8]. This study sought to evaluate the performance of unsupervised land cover change identification in dry situations

using various supplementary input data, where 1976, 1990, and 2002 Landsat satellite data were used. The Normalized Differential Water Index “NDWI,” Salinity Index “SI,” and Eolian Mapping Index (EMI) were all used. This study demonstrated that since 1990, desertification has worsened in the study area [9]. This study is to monitor the environmental changes and study the state of desertification in Al-Najaf province from 2015 to 2021 using combined indicators (NDVI, NDWI, BSI, NDBI) and proposing some solutions to reduce the encroachment of desertification towards residential areas and thus reduce its harmful effects.

2. Study Area

The study area is located in the Al-Najaf province, the north-eastern part, between the latitude ($37^{\circ} 55' - 30^{\circ} 00'$) N and the longitude ($43^{\circ} 55' - 44^{\circ} 35'$) E, covering about 3940.63 km^2 . Al-Najaf is located in the southwestern part of Iraq and has several borders with many provinces, including Anbar, Babylon, Qadisiyah, Muthanna, and Karbala. The Kingdom of Saudi Arabia borders to the south. The Al-Najaf province area covers about 28824 km^2 and constitutes about 6.6 % of Iraq [10]. Because it affects other environmental elements like water, soil, and air, the climate is one of the most crucial factors in environmental studies [11]. The research area is located within the hot desert climate, which is distinguished by extreme summer heat, while low temperatures are recorded in winter with low winter rain rates [12]. Iraq's land is part of the Arabian plateau, the eastern and northern parts of which have been affected by crust movements, tyranny, and the recession of the vast ancient sea. The area was flooded by sea during the second and early third geological periods and subjected to ground movements and pressure from the north, lifting some parts and landing others. The seabed to the south, represented by the sedimentary plain, has increased continuously due to massive sediment weight and internal movements, some of which are a part of the study area. The western basin sections of the Arabian Island Plateau, the most significant part of the study area (the Najaf Plateau), consist of solid mass rocks beneath them [13]; Figure (1) shows the study area map.

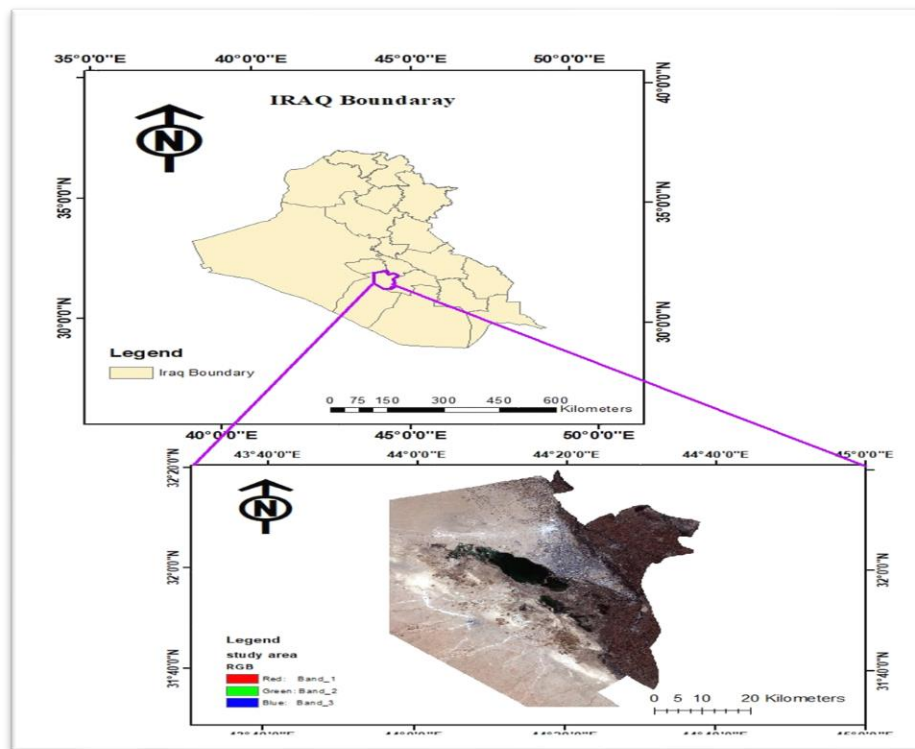


Figure 1: The study area map, country (Iraq), and province (Al-Najaf) (by author).

3. DATA USED AND METHODOLOGY

3.1 Data Used

Two Sentinel 2 satellite images were combined; the first was a Sentinel 2A image acquired on Dec. 26, 2015, and the second was the Sentinel 2B image acquired on Nov. 29, 2021, selected and downloaded from USGS.gov [14], which contained 13 bands. The mission will observe changes in earth's surface conditions, its wide swath width, and long revisit time (10 days at the equator with one satellite, and five days with two satellites under cloud-free conditions, resulting in 2-3 days at mid-latitudes) will make it possible to track changes in vegetation throughout the growing season [15]. as shown in Tables (1, 2). SNAP 8.0 was used for image processing, and ArcGIS 10.8 software was used for data analysis and map composition.

Table 1: The spectral bands of sentinel 2 [15]

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra-Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

Table 2: information about sentinel 2 images [15]

Sensor	Sentinel-2A	Sentinel-2B
Output format	JPEG2000	JPEG2000
Acquisition	26/12/2015	29/11/2021
Sun Elevation	57.96616954332°	55.4157847427856°
Cloud cover	0.000%	0.000%
Spatial resolution	10,20,60	10,20,60
Processing level	Level-1C	Level-1C
Datum	WGS84	WGS84
UTM zone	38N	38N
Map projection	UTM	UTM

3.2 Research method

The procedures include pre-processing stage, including radiometric and atmospheric correction, then image sub-setting to detect the change detection of the study area. The satellite image should be georeferenced in a coordinate system that matches real-world coordinates on the earth's surface, so the geometric correction was determined using UTM 38 and the 1984 World Geodetic System (WGS 84) [15].

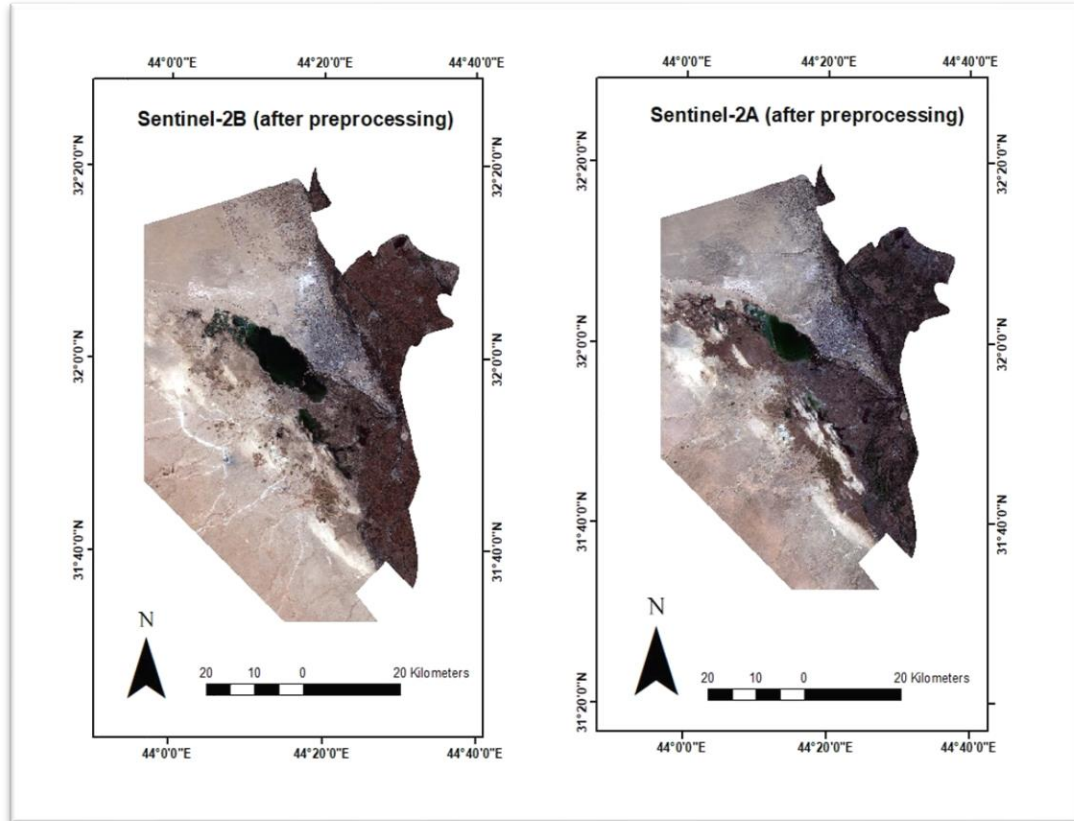


Figure 2: satellite images after pre-processing

4. Remote Sensing Indices

4.1 Normalized Differential Vegetation Index (NDVI)

Normalized Difference Vegetation Index is a widely used index of vegetation derived from remotely sensed electromagnetic energy observations in the red and near-infrared spectral regions. It determines whether the observed target contains live green vegetation or only bare land [16]. In the current study, NDVI was calculated from the periods of 2015 and 2021 data based on the normalized difference between the band 4 (Red) and band 8 (near-infrared) spectral values; the NDVI value ranges between (1, -1) with brighter values indicating pixels of green vegetation and darker values suggesting pixels with little or no vegetation, reflecting the state of vegetation cover.

$$NDVI = ((NIR - RED)/(NIR + RED)) \dots \dots \dots (1)$$

$$NDVI((sentinel2)) = ((B8 - B4)/(B8 + B4)) \dots \dots \dots (2)$$

4.2 Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index determines waterlogged areas and water bodies and improves their existence in remotely sensed digital imagery. The NDWI depends on reflected near-infrared radiation and visible green light to enhance the presence of such features while

removing soil and land vegetation features. Researchers may be able to get turbidity estimates for water bodies using remotely sensed digital data from the NDWI. Numerous water extraction methods have been developed and implemented for remotely sensed imagery [17]. The NDWI concept is based on the fact that there is a contrast between land and water. Water bodies have a low reflection in the SWIR and NIR bands, making detecting them possible.

The water index was calculated from the 2015 image and 2021 image data based on the following formula

$$NDWI = ((Green - NIR)/(Green + NIR)) \dots\dots\dots (3)$$

$$NDWI((sentinel2)) = ((B03 - B08)/(B03 + B08)) \dots\dots\dots (4)$$

Positive values (+1) for water features and negative (-1) or zero for soil and terrestrial vegetation are the results of the NDWI equation [7].

4.3 Bare Soil Index (BSI)

In order to measure soil variations, the Bare Soil Index “BSI” integrates the blue, red, near-infrared, and short-wave infrared spectral bands. These spectral bands are normalized before usage. Blue and near-infrared spectral bands are used to emphasize the presence of plants, whereas short-wave infrared and red spectral bands are utilized to measure the mineral makeup of the soil. This score was based on the capacity to distinguish between barren soil and vegetation land [18].

The bare soil index was calculated from the 2015 and 2021 images data based on the following formula

$$BSI = ((Red + SWIR) - (NIR + Blue))/((Red + SWIR) + (NIR + Blue))\dots\dots\dots (5)$$

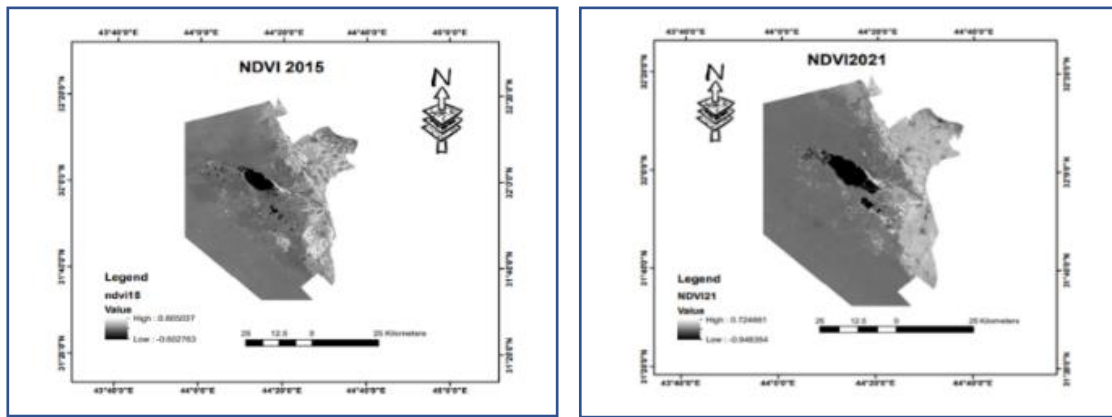
$$BSI((sentinel2)) = ((B11 + B4) - (B8 + B2))/(B11 + B4) + (B8 + B2)) \dots\dots\dots (6)$$

4.4 Normalized Difference Built-up Index (NDBI)

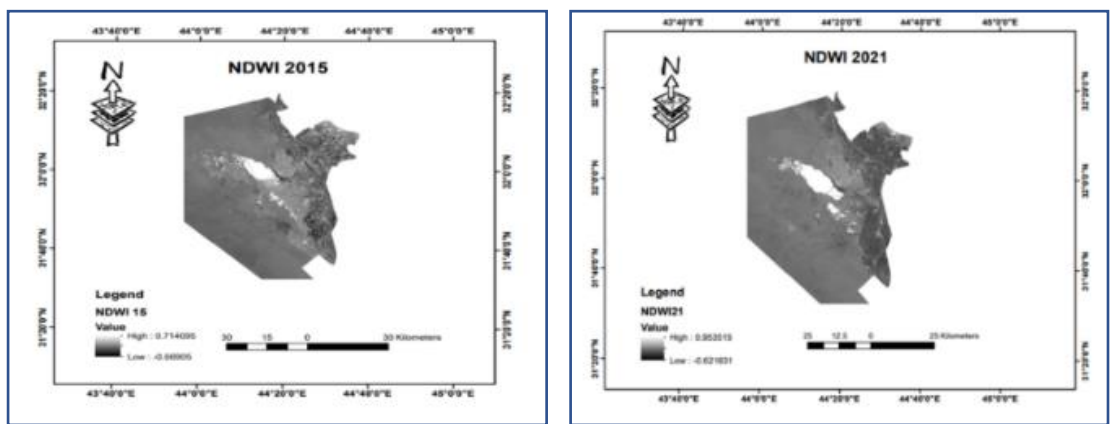
It is a spectral index used to examine urban areas, where Near-infrared (NIR) and Short-wave infrared (SWIR) are the two bands used in this index. Shortwave-infrared (SWIR) reflectance is higher in places with more built-up structures, while NIR reflectance is lower in areas with fewer built-up structures. The NDBI scale runs from -1 to +1; negative values indicate areas with no built-up buildings, and positive values indicate areas with densely built-up structures [19]. Normalized Difference Built-up Index was calculated from the 2015 and 2021 image data based on the following formula

$$NDBI = ((SWIR - NIR)/(SWIR + NIR)) \dots\dots\dots (7)$$

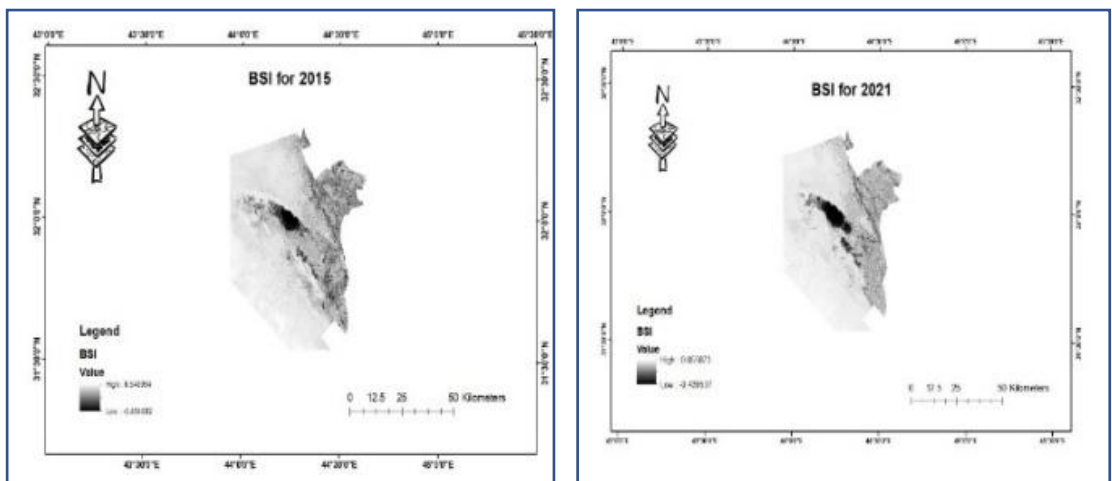
$$NDBI((sentinel2)) = ((B11 - B8)/(B11 + B8)) \dots\dots\dots (8)$$



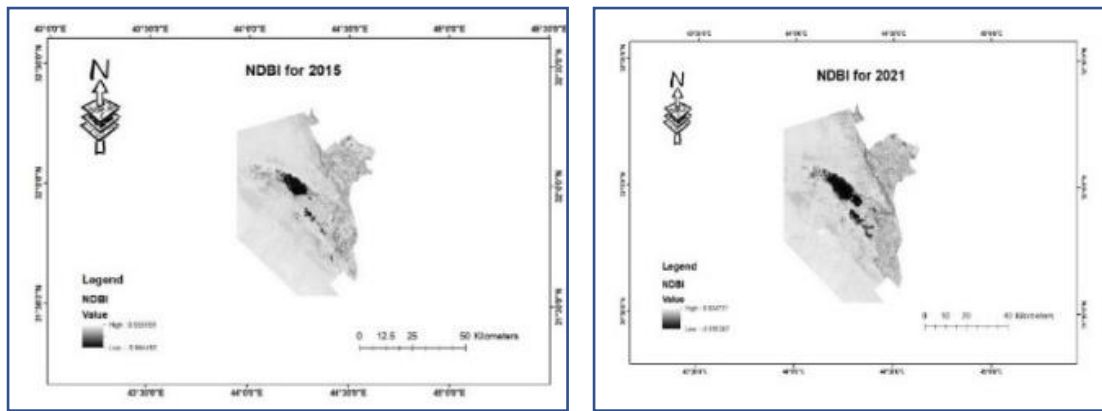
(a) (b)
Figure -3 This figure shows NDVI maps for (a) 2015, (b) 2021



(a) (b)
Figure 4: This figure shows NDWI maps for (a) 2015, (b) 2021



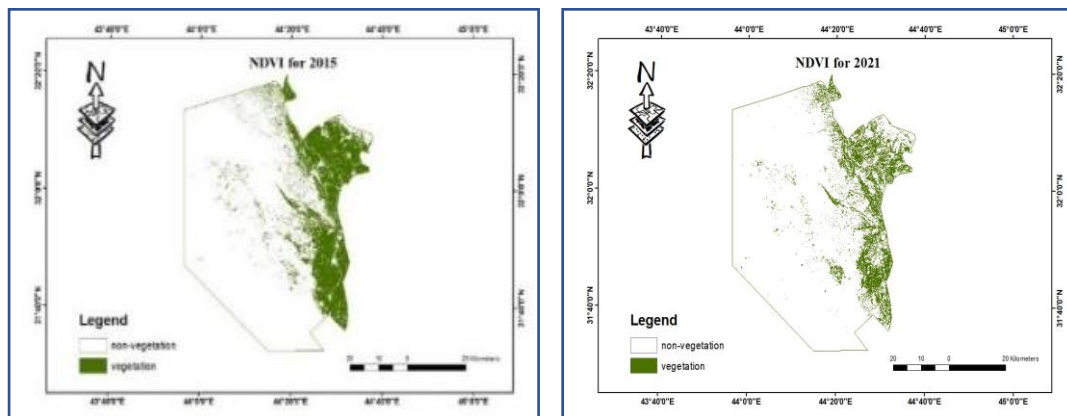
(a) (b)
Figure 5: This figure shows BSI maps for (a) 2015, (b) 2021



(a) (b)
Figure 6: This figure shows NDBI maps for (a) 2015, (b) 2021

5. RESULTS AND DISCUSSION

The area covered by vegetation was about 998.7 km² in 2015 and decreased to 921.5 km² in 2021. These outcomes were obtained by converting all NDVI raster data to vectors. The persistent vegetative has a dark green color on the cover, while the area without vegetation shows white. Figure (7) shows the difference in vegetation degradation from 2015 to 2021 and the decrease in vegetation cover from 2015 to 2021; the positive change in the NDVI's spatial distribution was in 2015, while the negative change was in 2021. The highest vegetation density areas are located in the research region's east, west, and southwest portions; entire agricultural areas have vanished with an apparent reduction.



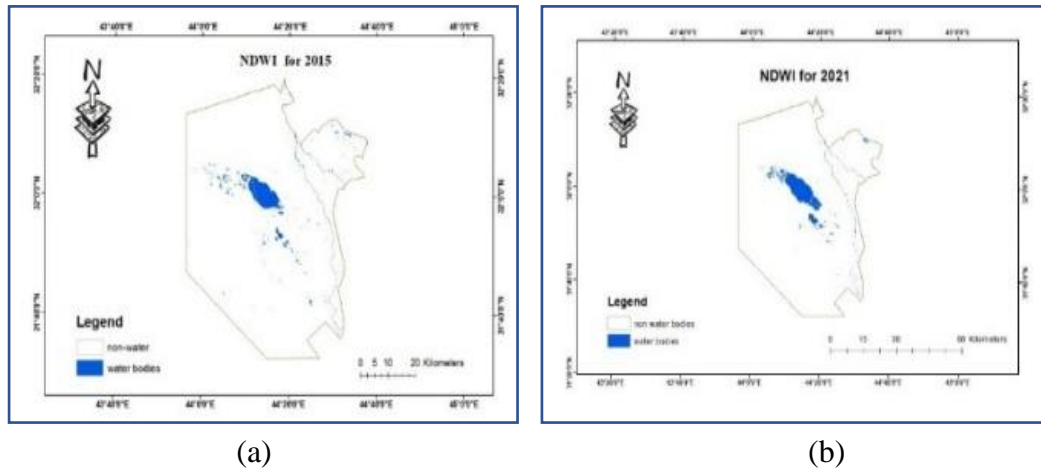
(a) (b)
Figure 7: The spatial distribution of the NDVI for (a) 2015, (b) 2021

Table 3: Percentage and vegetation area covered for each period

Year	Area of vegetation Km ²	Percentage of vegetation area to the total area
2015	998.72	25.34%
2021	921.53	23.39%

There was a noticeable increase in water bodies in 2021, which amounted to 170.98 km² and constituted about 4.34% of the total study area. In 2015, water areas showed a reduction, amounting to 145.87 km², constituting about 3.70% of the total area, as shown in Table (4).

This was due to the drying up of marshes, lakes, rivers, and streams, as well as the decrease in water revenues brought on by the natural and anthropogenic factors that have caused worsened to extreme levels of dryness and caused a shortage of rainfall. The region is desertified when NDWI ratios fall below 1 [20, 3]. Figure (8) shows the volume of water bodies between 2015 and 2021; the period with the highest water surface increase was 2021.

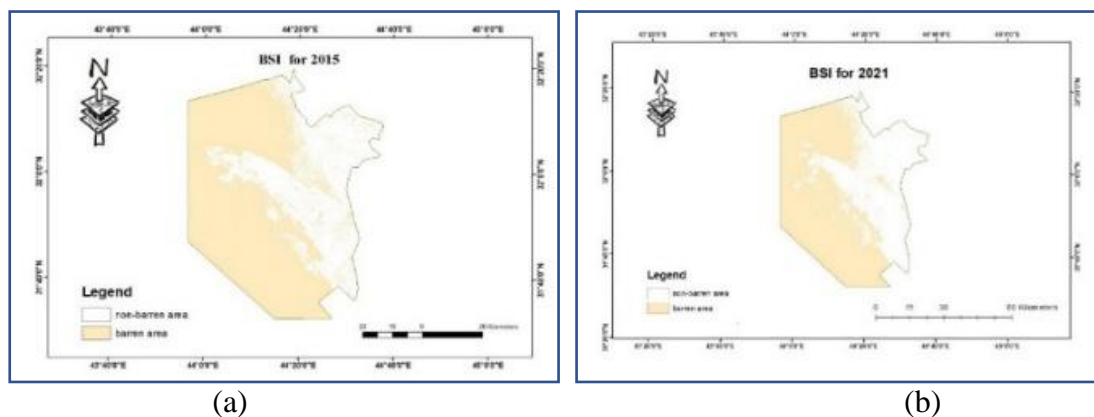


(a) (b)
Figure 8: NDWI maps for (a) 2015, (b) 2021

Table 4: Area and percentage of water bodies for 2015 and 2021

Year	Area of water bodies Km ²	Percentage of water bodies to study area
2015	145.869	3.70%
2021	170.978	4.34%

According to the reported results, dune accumulations in barren areas increased significantly over time, as did the moving rate in that direction. The highest accumulation rate of arid land was 1972.81 km² accounting for 50.06% of the entire research area in 2021, while 1857.47 km² accounted for 47.14 km² in 2015.

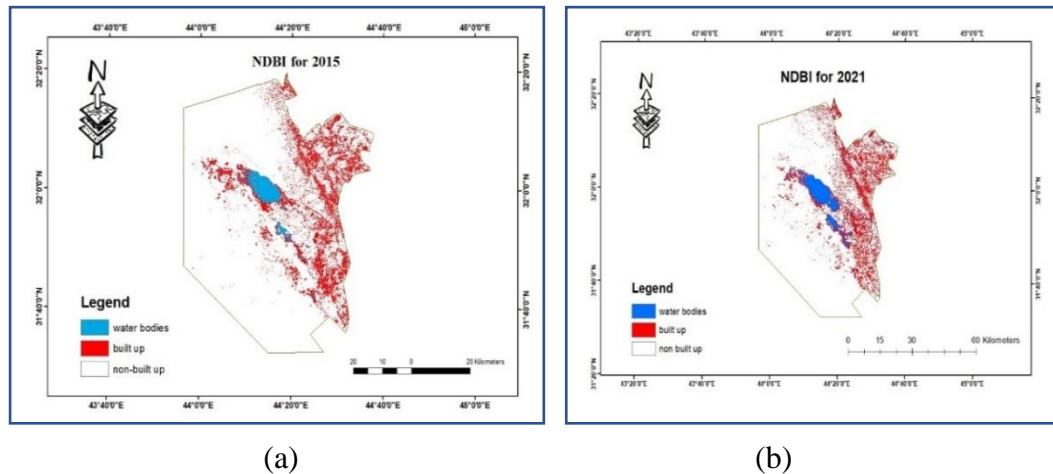


(a) (b)
Figure 9: BSI maps for (a)2015, (b)2021

Table 5: Area and percentage of barren area for each period

Year	Area of barren area Km ²	Percentage barren area to study area
2015	1857.47	47.14%
2021	1972.81	50.06%

Figure (9) shows an overall rise in buildings in the research area. The built-up area covered 458.66 km² in 2015 and 548.72 km² in 2021, which indicates an increase in the percentage of buildings. These results were adopted according to the NDBI for 2015 and 2021 [22, 23]. The NDWI and NDBI results were negative in 2015, while the NDVI and BSI results were positive; NDWI and NDBI results were positive in 2021 and NDVI, and BSI results were negative [24, 25]. In general, the area has had a faster rate of desertification [22].



(a) (b)
Figure 10: NDBI maps for (a) 2015, (b) 2021

Table 6: Area and percentage of urban area for each period

Year	Area of urban area Km ²	Percentage of the urban area to study area
2015	458.66	11.64%
2021	548.72	13.92%

6. CONCLUSIONS AND RECOMMENDATIONS

These conclusions can be made based on the results of the study. Remote sensing and GIS tools are the most valuable techniques for monitoring the desertification state and environmental changes. Monitoring and understanding desertification are essential for selecting appropriate control and prevention measures against the encroachment of desertification and dunes towards residential areas. The NDWI, NDVI, and BSI equations gave good water and bare land detection result from multispectral satellite data. The Sentinel 2 multi-time remote sensing data application provided an efficient and affordable method for mapping desertification processes in research and drylands. Showing desertification encroachment on the vegetation cover, the percentage of vegetation cover decreased in 2021. According to the NDVI analysis of the study area, the percentage was 24.14% in 2015 and decreased to 23.39% in 2021. The results of NDWI indicated an increase in water bodies in 2021 to 4.34%. The desertification rate increased by 50.06% in 2021, as indicated by NDB, while urban areas increased by 13.92%. The NDVI, NDWI, BSI, and NDBI have combined powerful technology to identify and map the process of desertification in the research area by offering precise measurement signals. The authors advise preserving vegetation from misuse and overgrazing as one of the essential means to protect the soil from erosion by wind and rainwater. The researcher proposes some solutions such as increasing vegetation cover, planting trees, planting drought-resistant crops, and focusing on the production of agricultural nurseries to increase the percentage of vegetation cover, which in turn serves as windbreaks and prevents dust storms, and purifies the air. creating oases and farms to combat desertification, especially in the western part of the region, which suffers from severe desertification, as well as utilizing d.

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