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Nanotechnology assessment of urban development and land surface temperature in Basra from 2000 to 2021 using rs and GIs methods

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Basra city in southern Iraq has undergone a high rate of urbanization over the past decades. Agricultural and open lands have been modified to populated regions. This paper has explored urban development space and time features as well as their effects on the climate of Basra. The analytical methodology of the study relies on the change of the Land Surface Temperature (LST), NDBI, and Land Use/Land Cover (LULC). The obtained data are analyzed and interpreted with the help of the Geographical Information System (GIS) technology. Based on Landsat 5 and Landsat 8 imagery, the change in urban growth and surface temperature of land between 2000 and 2021 is examined. The images that had been collected are classified using the unsupervised classification method, and this is done to determine the variation of LULC over the period. The results show significant variations in the LULC groups during the study period, mainly attributed to human activities. Throughout all the study years, the expanding urbanization of agricultural areas represented the main changes in the LULC. A total increase of 1,063 km^2 for the building areas is identified during the study period, which started with 4,788 km^2 in 2000 and reached 5,851 km^2 in 2021, mainly in the city center and northeast. As a result, a negative impact on the local climate is recorded as the temperature values rose from 1-67 ^{O}C in 2000 to 5-69 ^{O}C in 2021, with the highest temperature recorded in urban lands and bare lands lacking any vegetation.

Keywords: NDBI; LST; Basra city; RS; Nanotechnology.

1. INTRODUCTION

Nanotechnology is the study, design, and application of materials and devices at the nanoscale (about 1 to 100 nm). Compared to their bulk counterparts, materials at this scale frequently display distinct physical, chemical, and biological characteristics, such as increased conductivity, strength, lower weight, or chemical reactivity [1]. Globally, urbanization has become one of the main concerns in most major cities due to the rural-urban migration that has been intensified rapidly in search of better jobs and living standards. Thirty percent of people on the planet lived in cities in 1950; by 2050, this is projected to reach 66% [2, 3]. This twofold rise will cause numerous urban issues [4, 5]. Urban regions have experienced rapid spatial and demographic expansion over the past 50 years, outpacing the national growth rates in many countries due to their centralization as hubs for transportation and economic activities [6]. Accordingly, the ecosystem may be remarkably impacted by the changes of natural lands into impervious surfaces [7].

Among the various land use forces that affect the hydrology cycle of an area, urbanization is considered the most dominant [8]. The main definition of urbanization in hydrology is an increase in impervious surfaces, such as roads, roofs, pavements, parking areas, etc., caused by urban development, which in turn leads to a decline in the vegetation cover due to the growth in the urban and residential areas [9, 10]. In total, 54% of people live in cities around the world, and this percentage is predicted to rise [11, 12]. Most of the population around the world will be affected by climate change caused by anthropogenic activities in urban areas by 2030, when the land cover in these areas is expected to increase by 1.2 million km^2. Urbanization causes a reduction in the green cover, an increase in the impervious areas, and a change in albedo and geometry [13, 14], in addition to its contribution to the heat released from human activities compared to rural areas, and the phenomenon for cities that experience an increase in the temperature compared to the rural areas is called urban heat island [15, 16]. As temperatures rise, heat-related mortality will increase, which will be intensified by climate change [17]. Remote sensing with satellite imagery offers an efficient way to monitor land cover and its changes [18]. Rapid assessment relies on technologies such as change detection, which distinguishes image patterns [19]. Change detection identifies differences in objects or phenomena over time using multi-temporal data, revealing the temporal impacts on land cover [20]. Land cover is defined as vegetation, crops, buildings, and water, whereas land use is the way the human population exploits land, either as an open space, agricultural land, or housing. The LULC monitoring records the kind of areas of land that are in transition, by how much, and in what categories [21]. Remote sensing measures the land cover by identifying the change in the reflected ray of radiation, which depends on the land types, weather, soil moisture, and the sun angle [22]. The main aim of the study is to test the city growth and its impact on the land surface temperature of Basra and ascertain the nature of interdependence between the surface temperature and urban development.

AL-Hmedawy (2008) studied the geomorphological features and evaluated different forms and rates of the land surface change based on remote sensing information in Haur Al-Hammar and adjacent regions in southern Iraq. The research cited the human activities as the main factor that affects the landform formation with physical forces like water and wind also affecting the same. It is also mentioned that chemical factors have minor effect in the conditions of arid climate [23]. Suliman and Faroud (2015) examined the changes in location of sand dunes in the Thi-Qar Governorate, located to the north west of the current study area, using image indices. They saw scarce greenery, bare grounds, and growing sands dunes [24]. Fadhil (2009) discovered that there is significant land degradation and loss of water in some areas in northern Iraq [25]. The paper analyses how city growth has impacted land surface temperature of the Basra Governorate and analyzes the relationship between these variables with the help of remote sensing.

Nanotechnology is changing the land surface satellite technology, as it has led to making smaller, efficient and cheaper satellites (nanosatellites) and improving their parts to better Earth observation and data collection [1].

2. MATERIALS AND METHODOLOGY

2.1 Study area

The area of interest in this paper is the Basra Province of Iraq, with a total area of 19,070km2, whose latitude (30o 55.57- 29o 53.56N) and longitude (47o 59.15- 46o 37.55E) lie between them. Figure 1. The soil in Iraq is mainly of sedimentary nature in the central and the southern parts [26, 27]. The monsoon climate in the Province of Basra is characterized by the state of the atmosphere that is similar to that of the desert. It has hot summers, with July and August the hottest months at 45 oC, and an average temperature of 37.4 oC [28, 29]. The average annual rainfall is less than 100 mm, and the amount of the potential evapotranspiration may be more than 2,450 mm/year [30]. The northern part falls under the mesopotamian plain whereas the southern part falls under the Southern Desert in Iraq. To the north, it is surrounded by the River Euphrates, to the north west by Thi-Qar Governorate, to the west by Al-Samawa Governorate, to the east by Khur Al-Zubair, and to the south by Kuwait. The terrain of the area is flat with a few meters to less than 50 meters above the sea level and contains oil fields. The primary marsh of the study site is the Hor A-Hammar. The climate is warm to moderate, with hot, dry summers, especially in the desert [31]. From May to October, the average humidity remained below 50%. This results in low rainfall during most months, further soil erosion, and dust storms. Summer temperatures can exceed 45 ºC. The investigated area is classified as having an arid climate based on Peltier's [32] climatic categorization, which is typified by short winters with little seasonal rainfall and long, scorching summers with sporadic dust storms. Precipitation is most common between October and March [33].

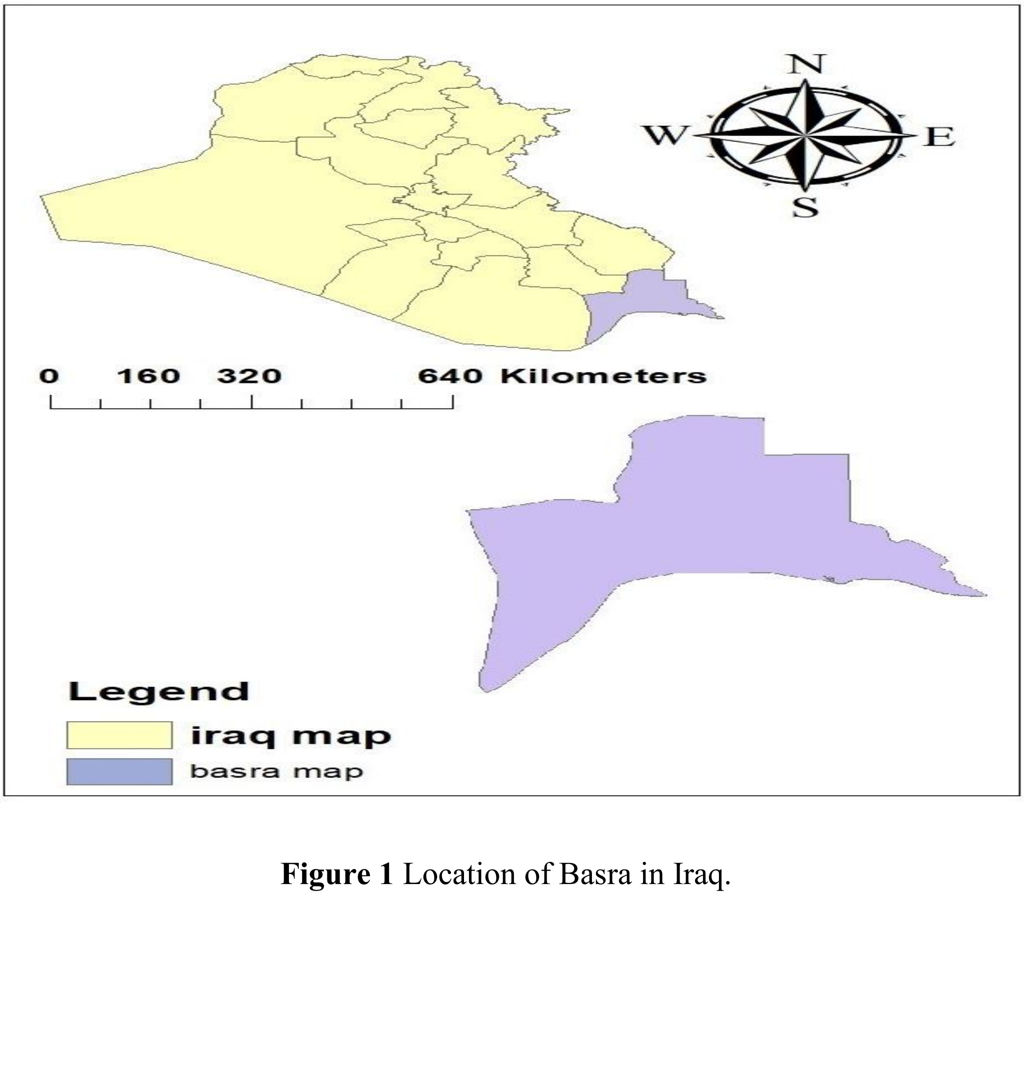

Figure 1 Location of Basra in Iraq.

2. 2 Pre-processing
2.2.1 Dataset Acquisition

The USGS website (https://earthexplorer.usgs.gov) is used to obtain satellite data (Landsat 5 with sensor TM (Path/Row: 165/39, 166/38, 166/39, 166/40) and Landsat 8 with sensor OLI (Path/Row: 165/39, 166/38, 166/39, 166/40)) to determine the changes in buildings and land surface temperature in this study. Landsat 5 and Landsat 8 images from 2000 and 2021, respectively, are used for the two-year study. The satellite data used in the investigation are displayed in Table 1. In addition to transforming digital values (DN) into radiance and reflectance values, the satellite-collected photos are digitally processed using GIS 10.7 software to display the buildings and analyze the surface temperature. Figure 2.

Table 1 The satellite details used in the study.

NO	SATELLITE TYPE	SENSOR	DATE	RESOLUTION
1	Landsat 5	TM	13-11 & 22-11-2000	30
2	Landsat 8	OLI	16-11 &23-11-2021	30

2.2.2 Image Pre-processing

- Correct for atmospheric effects
- Apply radiometric calibration to convert the digital numbers to reflectance values.
- Perform geometric correction to eliminate distortions caused by the sensor position and Earth's curvature.

2.2.3 Subset and Mosaic

- Basra City needed four days to cover it
- In the mosaic process, the four senses combine to create a seamless composite image.

2.2.4 Image Enhancement (Optional)

- To enhance visual interpretation, image enhancement techniques (i.e., contrast stretching and histogram equalization) are used.

2.2.5 NDBI Calculation: NDBI is calculated using the following formula [34]:

$$\text{NDBI} = \frac{\text{SWIR} - \text{NIR}}{\text{SWIR} + \text{NIR}} \tag{1}$$

SWIR and NIR denote the reflectance values in the shortwave infrared and near-infrared bands, respectively.

- Calculate NDBI of every pixel in the image by using the above mentioned formula.
- The values obtained in the NDBI are between -1 and +1 with the positive values indicating built-up areas.

2.2.6 Data Interpretation

- Average out the NDBI image to detect the built-up areas. Through the process of thresholding, a value above which pixels are classified as built-up is set.
- Determine the appropriate threshold value by considering the characteristics of Basra City.

- Convert the threshold image to a binary format, where built-up areas are represented by white pixels and non-built-up areas by black pixels.

2.2.7 LST calculation

Thermal Infrared (TIR) bands and associated calibration parameters are used to calculate the Land Surface Temperature (LST). Radiative transfer equations and algorithms are applied to convert TIR values to temperature values, considering emissivity and atmospheric effects.

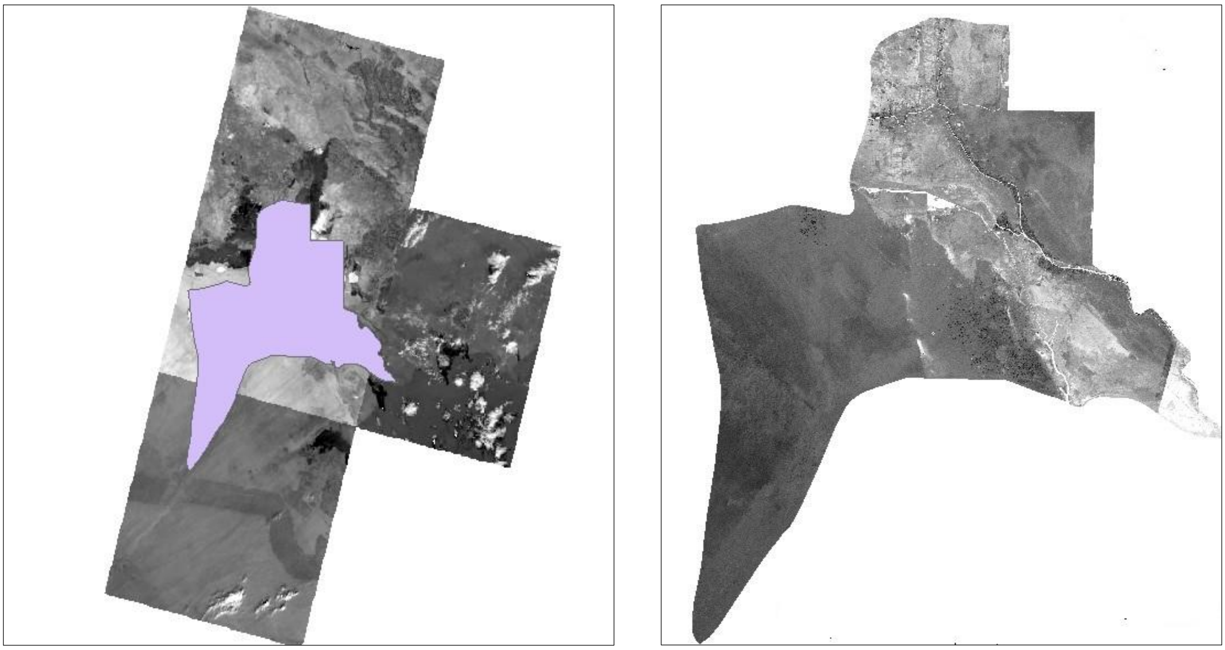

Figure 2 Mosaic of four scenes for Basra city and the extraction of the study area.

3. RESULTS AND DISCUSSION

The remote sensing images of Basra for the years 2000 and 2021 for November are processed using ArcGIS v.10.7 software. For better accuracy in extracting the built-up classification from the other land use/land cover classification in the images of Landsat 5 and Landsat 8, the NDBI equation (Equation No.1) is used to determine the spatio-temporal variation in building areas in Basra city for the years 2000 and 2021. In this study, the differences are displayed for the building block using the blue and near-infrared bands, and the results are presented in Figure 3 and Table 2. Basra shows a spatial and temporal variation based on the building index values for 2000 and 2021, with values ranging from -0.56 to 0.86 and from -0.77 to 0.28 in 2000 and 2021, respectively.

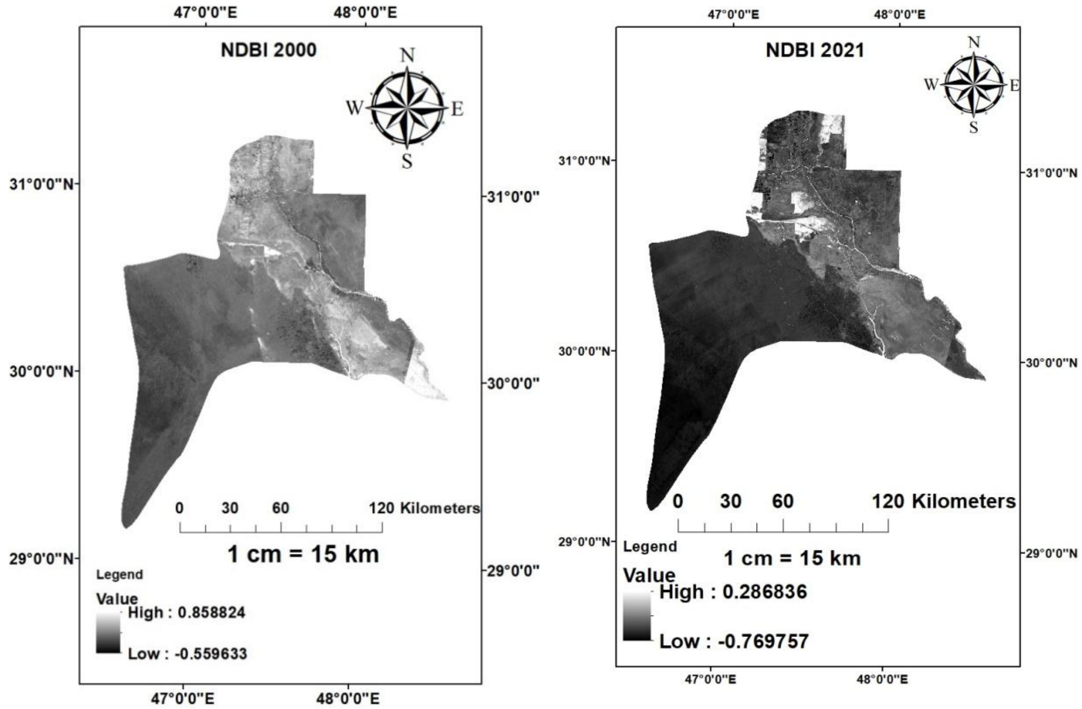

Figure 3 The NDBI for Basra city in the years 2000 and 2021.

Table 2 NDBI values for the years 2000 and 2021.

NO	YEAR	MIN	MAX
1	2000	-0.559	0.85
2	2021	-0.769	0.28

The unsupervised classification method is used for the built-up images. Based on the results represented in Table 3 and Figure 4, it is evident that there is a spatiotemporal variation in the area of built-up classification, which is demonstrated by a continuous increase throughout the study period from 2000 to 2021, with a total growth of 1,063 km² that started with a building area of 4,788 km² in 2000 and reached 5,851 km² in 2021. The majority of this increase is concentrated in the center and northeast of Basra, which is consistent with the growth rate of Basra's population, with some occasional differences that can be attributed to the changes that occurred in the economic conditions of the people in Iraq during the study period, which in its turn affected the urban development and its impact on the agriculture in the study area.

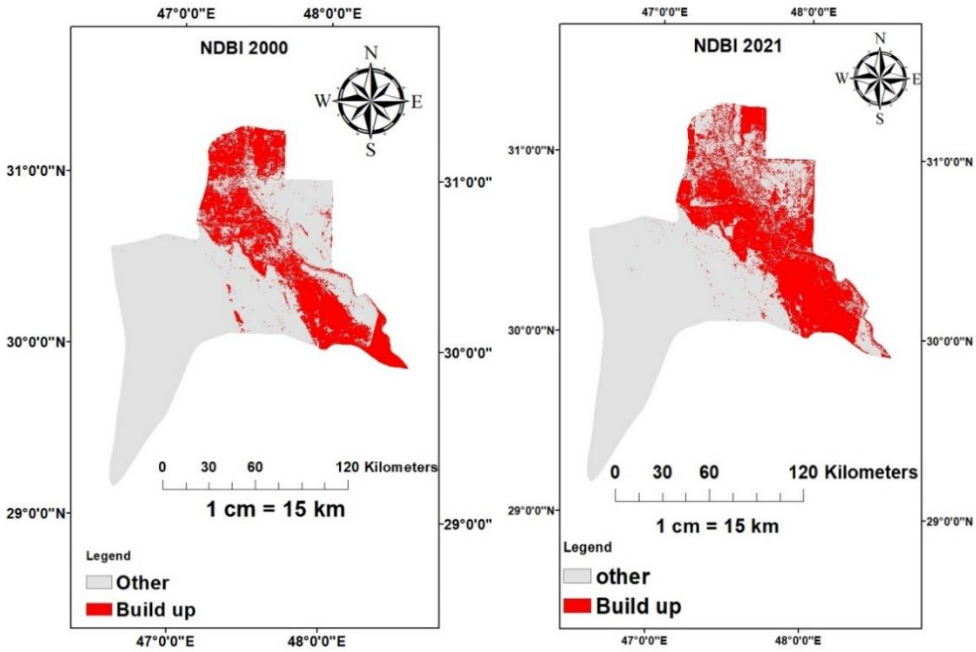

Figure 4 Unsupervised classifications of the NDBI for Basra City (2000-2021).

Table 3 Built-up areas for the study years.

NO	YEAR	BUILT-UP	OTHERS
1	2000	4,788 km^2	13,298 km^2
2	2021	5,851 km^2	12,235 Km^2

Figure 5 illustrates that the LST increased from (1-67 ^{O}C) in 2000 to (5-69 ^{O}C) in 2021. The highest values of LST are concentrated in the city center and eastern Basra, northeastward. The increase in LST values can be accounted for by converting agricultural and open areas into inhabited areas for industrial and commercial purposes, in addition to the wide squatter settlements that Basra witnessed after 2003.

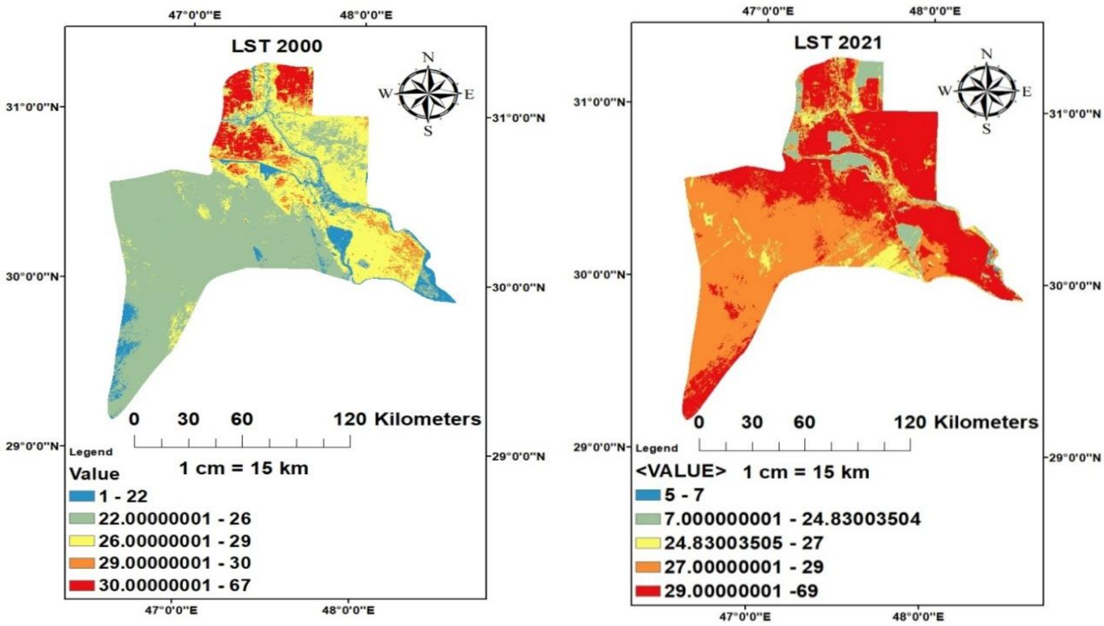

Figure 5 LST for Basra city at (2000, 2021).

4. CONCLUSIONS

This study presents a statistical method to examine how urbanization and land use/ land cover changes affect Basra's city climate in November for the selected years 2000 and 2021. The results revealed the following:

1. The impact on the local climate for 2000-2021 was attributed to the changes in the land use/ land cover due to human activities.
2. Between 2000 and 2021, the building areas in the city expanded from 4,788 km^2 to 5,851 km^2.
3. During November, the surface temperature increased from (1-67 ^{O}C) in 2000 to (5-69 ^{O}C) in 2021. The temperature reached maximum levels mainly in the residential areas and bare lands without vegetation cover in the city center and eastern Basra northeastward.
4. There was a positive correlation between LST and NDBI. Urban expansion often leads to the loss of vegetation. As vegetation decreases, the normalized difference vegetation index (NDVI) drops, while the NDBI rises, leading to higher surface temperatures. Man-made surfaces tend to have a lower albedo than natural surfaces, meaning they absorb more solar radiation and contribute to increased LST.

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