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Land Surface Temperature investigation of Babylon city between (2002-2022) using Remote Sensing and GIS Technique

Khalid H. Abbas Al-Aarajy*, Zainab H. Mohammed Hassan

Department of Remote Sensing and GIS, College of Science, University of Baghdad, Lab. of Seismology and Spatial Data Analysis, Baghdad, Iraq

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Abstract.

Land surface temperature (LST) is crucial for determining the region's environmental quality because a significant temperature rise causes disasters, which cause environmental imbalance, reducing biodiversity and hastening desertification. In this study, remote sensing and geographic information systems were used to estimate the change in the LST of Babylon, Iraq, using two satellite images taken 20 years apart (2002, 2022). The temperature was extracted using a specific mathematical model in ArcMap10.8 software. The findings demonstrated a significant variation in temperatures and the concentration in various regions of Babylon between 2002 and 2022 and the relationship between LST and Normalized difference vegetation index. The most significant element that causes a shift in the LST is the spread of urbanization in Babylon at the expense of vegetation and unused land.

Keywords: Land surface temperature, LULC, NDVI, correlation.

استقصاء درجة حرارة سطح الأرض لمدينة بابل بين (2002–2022) باستخدام تقنية الاستشعار عن بعد ونظام المعلومات الجغرافية

خالد حسين عباس, زينب حسين محمد حسن

جامعة بغداد/ كلية العلوم /قسم التحسس النائي ونظم المعلومتات الجغرافية

الخلاصة

تعتبر درجة حرارة سطح الأرض (LST) أمرًا بالغ الأهمية لتحديد الجودة البيئية للمنطقة لأن الارتفاع الكبير في درجة الحرارة يمكن أن يتسبب في حدوث كوارث ، والتي بدورها يمكن أن تسبب اختلالًا بيئيًا ، مما يقلل من التنوع البيولوجي ، والذي تعتمد صحته على توازن البيئة ، و يمكن أيضا أن تسرع من التصحر. في هذه الدراسة ، استخدمنا الاستشعار عن بعد ونظم المعلومات الجغرافية لتقدير التغيير في LST في محافظة بابل باستخدام صورتين فضائيتين تم التقاطهما بفاصل 20 عامًا (2002 ، 2022). باستخدام أدوات مثل أدوات التحليل المكاني في برنامج (ArcMap10.8) ، تمكنا من استخراج درجة الحرارة باستخدام موديل رياضي خاص . أظهرت النتائج التباين في درجات الحرارة وتركيز درجات الحرارة في مناطق مختلفة في بابل مقارنة بين عامي 2002 و 2022 ، وكذلك العلاقة بين LST و NDVI. العنصر الأكثر أهمية الذي يسبب التحول في LST هو انتشار التحضر في بابل على حساب الغطاء النباتي والأراضي غير المستخدمة.

Email: khalidhussein66@yahoo.com

Introduction

Landscape Changes can be attributed to natural and artificial factors. Significant landscape changes have occurred in recent decades, primarily due to rapid urbanization, which causes an increase in land surface temperatures (LST). Urban areas account for 54% of the world's population. They are constantly subject to intricate interconnections between regional exploitation and economic development. Resulting in a shift in land use and land cover (LULC), which impacts the city's geophysical state and causes environmental disturbances like climatic and LST changes [1]. The key factors affecting urban climate (LST) are used to measure urban heat islands (UHIs). Which. are the day Length, seasons, winds, currents, clouds, topography, location, rural environment, land use change, building materials, and urban shape all have an indirect but significant impact on surface temperature in urban areas. This is especially true for the crown layer closest to the surface. The vegetation-covered green spaces serve as the city's "lungs" and help in temperature control, resulting in low temperatures in the local vicinity [2]. According to research on LST, the partitioning of heat fluxes and subsequent surface energy response results from variable surface soil water content and plant cover. LST data typically represent the radiant temperature of a sunny, bare surface, such as bare ground. The radiant temperature measured by the sensor approaches the green leaf temperature as vegetation cover increases and canopy temperature at maximum or full canopy cover for spectral vegetation. [3]. During the research, the change in the surface temperature was studied for 20 years between 2002 and 2022 in Babylon, using high-resolution images from Landsat 7 and 8, and the correlation between the land surface temperature and NDV, LULC was found. Also, a new technology of the GIS program was used to determine the areas with temperatures more than 45C.

Methodology :

1. Land Surface Temperature (LST) Model

The radiant surface temperature was obtained from radiometrically corrected thermal infrared data (band 6 form ETM+), and (TIRS was derived from bands 10 and 11). To obtain LST, the digital number (DN) must be converted to radiance using the formula below [4].

$$CVR = G\,(CVDN) + B \qquad \ldots (1)$$

Where :
CVR: is the value of cell radiance.
G : is the gain value .(0 .00033420 was use in this study)
CVDN: is the (digital number) (DN) of the bands 6 and 10.
B-: is the (offset value).
In order to determine the brightness temperatures in kelvin (k) from radiance images obtained from thermal bands, the following equation was utilized [5] :

$$T_k = K2 / \ln(K1 / C_{VR} + 1) \qquad \ldots (2)$$

Where :
T_K: is the brightness temperature per Kelvin (K).
K2: is the prelaunch calibration constant 2 per Kelvin.
K1: is the prelaunch calibration of constant 1 in a unit of W/(m^2sr·μm).
To convert the brightness temperature from Kelvin to Celsius degree by

$$: \; (C° = T_k - 273.15) \qquad \ldots (3)$$

NDVI is a primary numerical index used to analyze remote platform sensing data and determine whether a target or object being viewed has bright green vegetation [6]. It has been discovered that the normalized difference vegetation index (NDVI) is a reliable predictor of land surface temperature [7]. The equation below is used to compute the NDVI :

$$NDVI = ((NIR - Red) / (NIR + Red)) \qquad \ldots (4)$$

Once NDVI was calculated for each satellite image, the Portion of vegetation was estimated by using equation (5):

$$Pv = ((NDVI - NDVI"min")) / ((NDVI "max" - NDVI"min"))2 \quad \ldots(5)$$

Pv: Portion of vegetation

Vegetation coverage was calculated from NDVI images of the study area [8]. in the NDVI images, land surface emissivity can be defined as the average emissivity of elements on the earth's surface calculated using equation (6).

$$E = 0.004 * Pv + 0.986 \quad \ldots (6)$$

Where :

E is (Land surface emissivity)

PV is (Proportion of vegetation)

- 0.986 is added as a correction value to the equation.

LST based on satellite brightness temperature is calculated by the following formula: [9]

$$LST = C° / (1 + (\lambda * T_k / \alpha) \ln (E)) \quad \ldots (7)$$

LST is the Land Surface Temperature per Celsius.

C ° is the brightness temperature per Celsius.

λ is the (wavelength of the emitted radiance) per meter.

α: 1.438×10^{-2} mK.

E is the (Land surface emissivity)

2 . The Study Area And Available Data

The study area is the administrative district of Babylon in Iraq, between 43.998E-45.214E longitude and 33.041N-32.094N. Babylon covers an area of 5469.45 km^2. It is located in the central region of Iraq and is characterized by its flat surface; it suffered an increase in temperatures due to the decline of vegetation and the expansion of buildings.

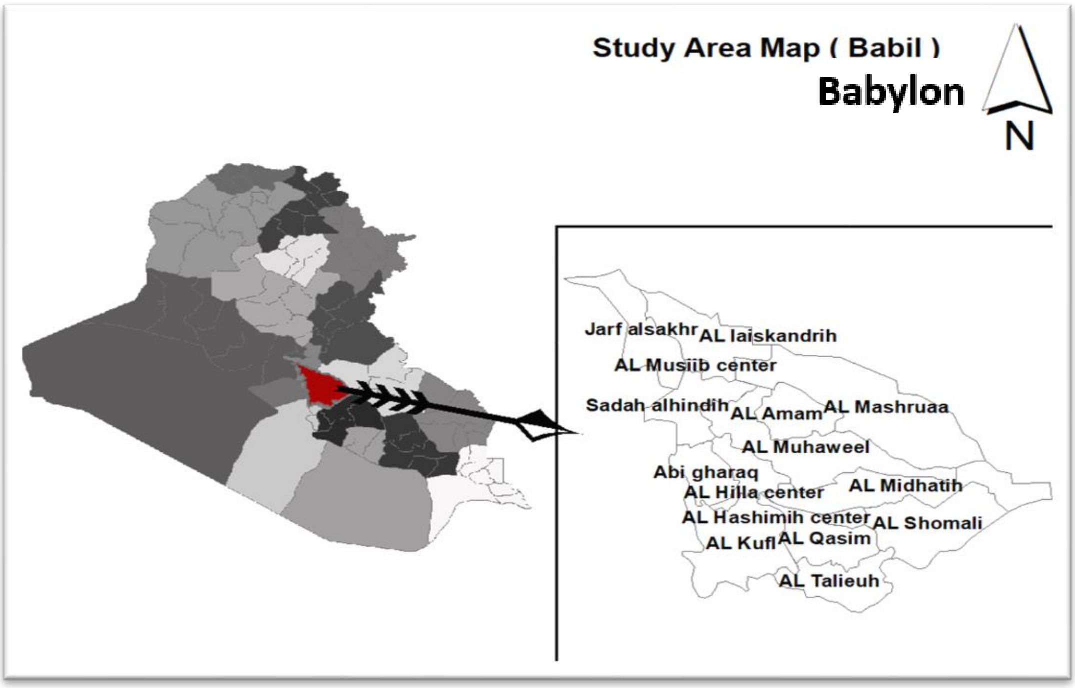

Figure 1: (Babylon Governorate map)

Time series of Landsat imagery acquired by the Landsat Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) and Landsat ETM+ sensors served as the major data sets for the investigation. The information is displayed in Table (1); the satellite data that chosen satellite data was chosen was cloud-free.

Table 1: The details of satellite imagery obtained.

Satellite.	Sensor.	(Acquisition) Date	Cloud Cove	Spatial Resolution	Source.
Landsat 7	ETM+	2002/08/05	0%	30	USGS
Landsat 8	OLI/TIRS	2022/07/19	0%	30	USGS

3 . Results and Discussions

3.1: Land Use and Land Cover (LULC) Numerous cover reasons and mechanisms contribute to land use and cover change. Geomorphology and edaphic variables govern the distribution of LULC on the landscape. In contrast, climate, technology, and economics are essential determinants of land-use change at various geographical and temporal scales. Numerous factors influence the existence and evolution of LULC at a particular time and place. These variables include driving elements: political, economic, cultural, technological, and natural; also, variables resulting from the spatial layout (known as natural configuration) and site variables (spatial organization, topography, and soil conditions). Natural disturbances such as droughts, wildfires, and floods that cause long-term changes are examples of natural factors. [10]. The classification result of Babylon in (2002 and 2022) are shown in Figure (2); the percentage of each class are summarized in Table (2).

Table 2 : The supervised classification details

2002			
Class name	**COUNT**	**Area/Km^2**	**%**
Building	751191	676.0719	12
Unused Land	2670845	2403.7605	44
Vegetation	2611748	2350.5732	43
Water	43400	39.06	1
Total		**5469.466**	**100**
2022			
Class_name	**COUNT**	**Area/Km^2**	**%**
Building	1666527	1499.8743	27
Unused Land	2373126	2135.8134	39
Vegetation	1923137	1730.8233	32
Water	114393	102.9537	2
Total		**5469.465**	**100**

In the LULC maps of Babylon, as shown in Figure (3), there is an urbanization expansion of about (12%) in 2002, while in 2022, it was (27%). The vegetation also decreased where the vegetation in 2002 was about (43%), and in 2022 it was about (32%). The increase in urbanization and decrease in vegetation leads to higher temperatures. Therefore there is a strong relationship between LULC and LST.

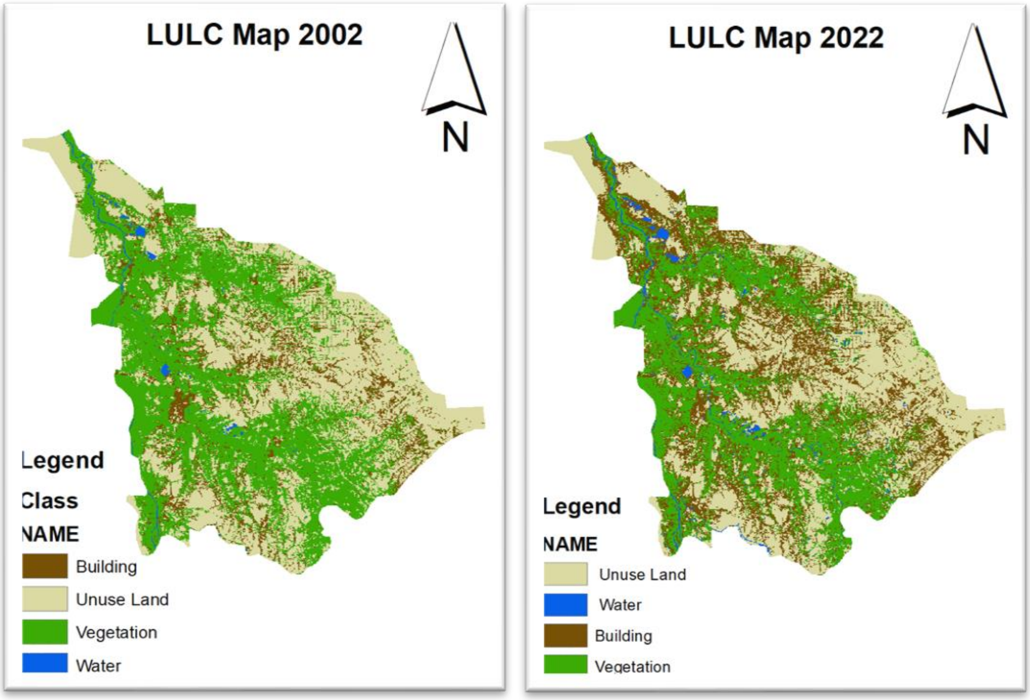

Figure 2: (land use and land cover for Babylon)

3.2: Normalized Difference Vegetation Index (NDVI), a method for measuring vegetation cover changes. The NDVI relates red and near-infrared spectral information to provide a variable that can estimate vegetation's quantity, quality, and evolution. Visible and near-infrared bands of multispectral satellite sensors can monitor vegetation greenness or vigor. The so-called vegetation index is frequently used in vegetation studies [12]. The NDVI estimated the percent vegetation cover in varied topographical characteristics and vegetation cover at Babylon Figure (4); green represents vegetation areas, and blue represents water.

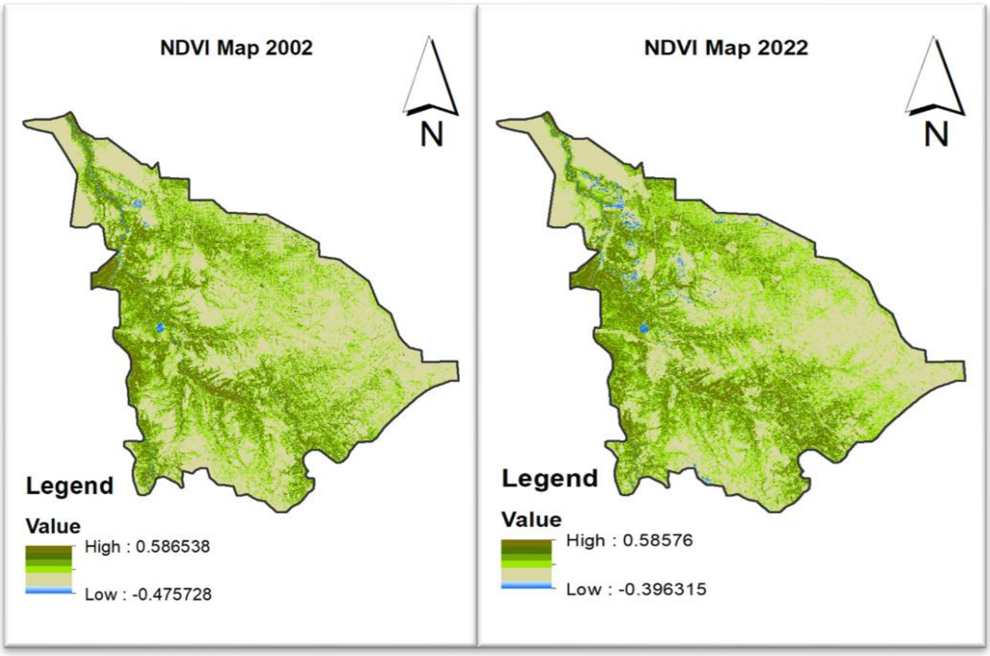

Figure 3 : Normalized Difference Vegetation Index)

3.3: Land Surface Temperature (LST): Seven equations mentioned before were used to estimate the LST: Equation (1) is to convert the pixel value to radiance. This yields a measure of the radiance of thermal infrared radiation rising from the top of the atmosphere to the satellite, expressed in temperature units. Then the peak temperature of the brightness of the atmosphere" [11] is given by the formula obtained using equation (2); because the output value was in Kelvin, equation (3) was converted to Celsius. After getting the NDVI and Land surface, the Emissivity equation (7) was used to get the LST. As shown in Figure (4), the LST changed significantly between 2002 and 2022. The red hue denotes the greatest temperatures, and the blue denotes the lowest temperatures, which correspond to water; the temperatures (red regions) rose, and the green regions were reduced.

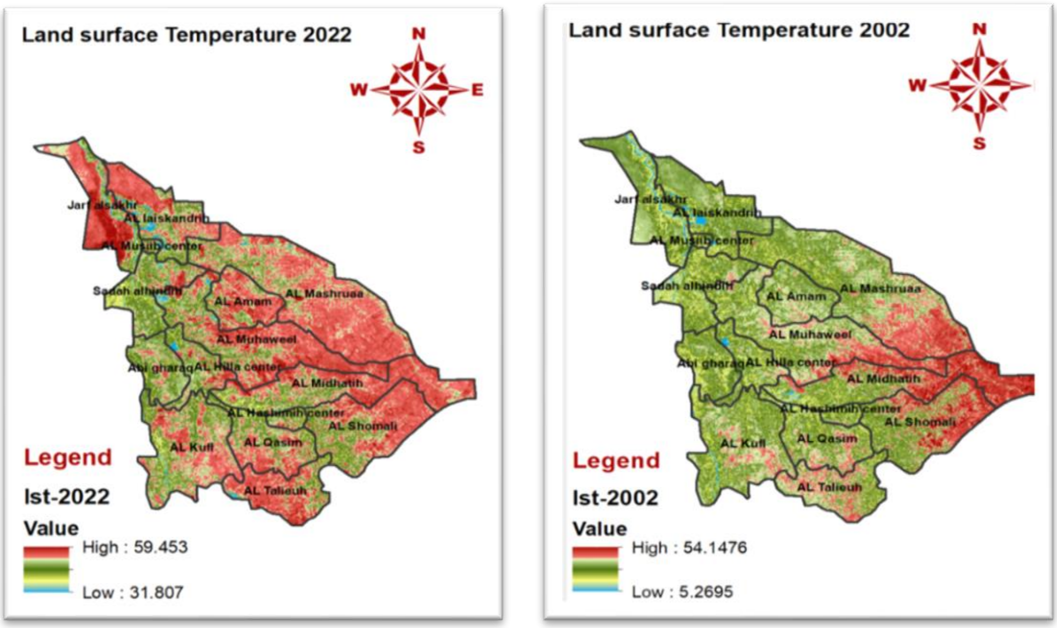

Figure 4: Land Surface Temperature (LST)

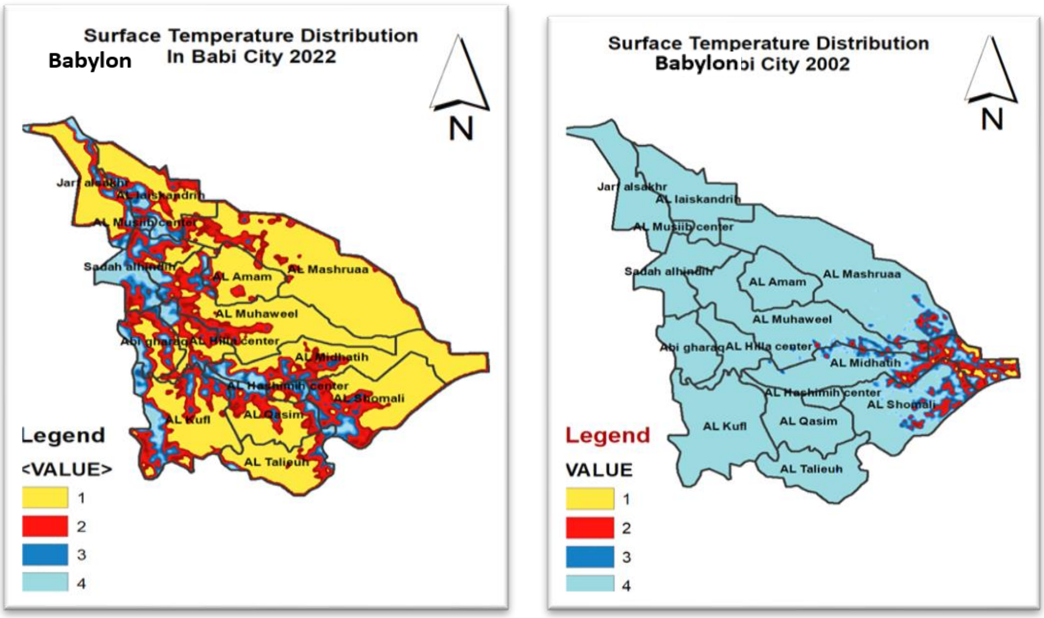

Figure 5 : (Surface Temperature Distribution)

In Figure (5), the surface temperature distribution for Babylon between 2002 and 2022 was extracted, ranging from 45C to the greatest degree in each year. Where number 1 is colored yellow, representing areas with the highest temperature concentration (High concentration of points reflecting temperature above 45C). Numbers 2 and 3 are red and dark blue, respectively, indicating areas with lower temperature concentrations. Number 4 is colored light blue, showing areas with temperatures below 45 C. There has been a significant change between 2002 and 2022.

3.4: Relationship between NDVI and LST: Sample points randomly selected from LST and NDVI were used to construct the correlation and were then depicted graphically with a 2D scatterplot in Figures (6) and (7). As shown, the relationship is negative, meaning that as the NDVI rises, the LST falls and vice versa.

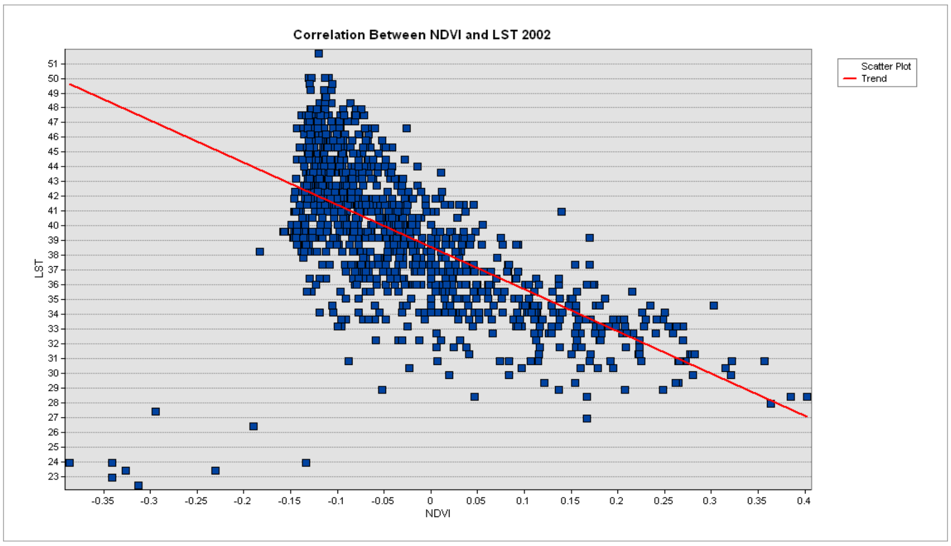

Figure 6 : (Correlation between NDVI and LST 2002)

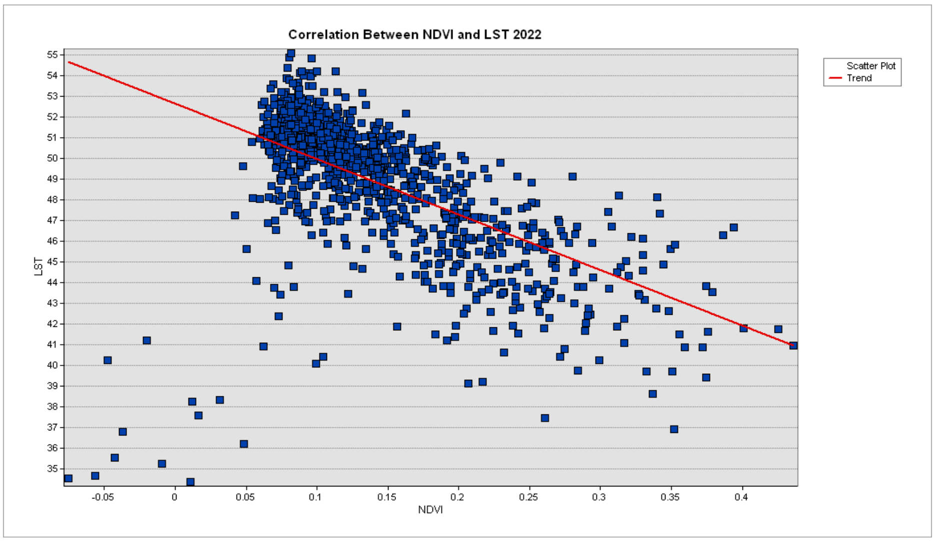

Figure 7: (Correlation between NDVI and LST 2022)

4 . Conclusion

The assessment showed the Land Surface Temperature (LST) changes in Babylon using remote sensing and GIS technology for 2002 and 2022. So noticing that building expansion was at the expense of vegetation and bare land areas between 2002 and 2022. The city's territory showed an increase in urbanization by 15%. In contrast, the increase in water space was by 1% resulting in the growth of several fish lakes. Due to the emphasis on urban growth and the disregard for vegetation covers in Al-Mashruaa, Al-Amam, Al-Qqasim, and Al-Muhaweel in Jarf Alsakhr and Al-Aiskandrih are the most locations that have been exposed to an extreme rise in temperature. The improper land use management in Babylon led to an alarming and negative contrast of temperatures by comparing the past and current. The ongoing loss of vegetation causes a permanent threat to the ecological balance in the area because of the inverse relationship between LST and NDVI. That means a continuous rise in temperature, which renders the land uninhabitable.

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