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Relationship of LST, NDVI, and NDBI using Landsat-8 data in Duhok city in 2019-2022

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Abstract

One of the most significant elements influencing weather, climate, and the environment is vegetation cover. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) over the years 2019–2022 were estimated based on four Landsat 8 TIRS's images covering Duhok City. Using the radiative transfer model, the city's land surface temperature (LST) during the next four years was calculated. The aim of this study is to compute the temperature at the land's surface (LST) from the years 2019-2022 and understand the link, between LST, NDVI, and NDBI and the capability for mapping by LANDSAT-8 TIRS's. The findings revealed that the NDBI and the NDVI had the strongest correlation with the value R 2 = 82 in the year 2022. In comparison to the Normalized Difference vegetation index(NDVI), there was a relatively larger correlation between the NDBI and the surface temperature. However, the Normalized Difference Building up Index (NDBI) and temperature were determined to have the smallest correlation.

Keywords: Land Surface Temperature; NDBI; NDVI, Duhok city

مجلة المخطط والتنمية
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العلاقة بين LST و NDVI و NDBI باستخدام بيانات Landsat-8 في مدينة دهوك بين عام 2019-2022

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الخلاصة

يعتبر الغطاء النباتي هو أحد أهم العناصر التي تؤثر على الطقس والمناخ والبيئة. ركزت هذه الدراسة على تقدير قيمة مؤشرين هما : مؤشر الفرق الطبيعي للغطاء النباتي (NDVI) ومؤشر تراكم الفرق الطبيعي (NDBI) على مدار أربع سنوات في الفترة الزمنية (2019-2022) وذلك بالإستناد على أربع صور من الأقمار الصناعية من خلال (Landsat 8 TIRS) والتي تغطي مدينة دهوك بالكامل خلال الفترة المذكورة ، حيث إستخدمت الدراسة نموذج النقل الإشعاعي لحساب درجة حرارة سطح الأرض (LST) في المدينة خلال تلك الفترة الزمنية . كان الغرض من هذه الدراسة هو حساب درجة الحرارة على سطح الأرض (LST) في الفترة الزمنية (2019-2022) وفهم مدى الارتباط بين LST و المؤشرين (NDVI و NDBI) وكذلك بيان القدرة على إمكانية رسم الخرائط بواسطة (LANDSAT-8 TIRS & 39 # ؛ ق)لبيان تلك العلاقة . وعليه أظهرت نتائج البحث أن المؤشرين (NDBI و NDVI) كان لهما أقوى ارتباط مع القيمة (R2 = 82) في سنة 2022 . وبالمقارنة مع مؤشر الفرق الطبيعي للغطاء النباتي (NDVI) ، تبين أن هنالك علاقة ارتباط أكبر نسبيًا بين مؤشر (NDBI) ودرجة حرارة السطح في المدينة . ومع ذلك تم تحديد مؤشر تراكم الفرق الطبيعي (NDBI) ودرجة الحرارة ليكون لهما أصغر ارتباط .

الكلمات الرئيسية: درجة حرارة سطح الأرض ، NDBI ، NDVI ، مدينة دهوك

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مجلة المخطط و التنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10

Introduction

Changes in urban design and function together have altered the urban heat balance, causing local warming at the intra-urban scale, which has caused great worry among urban academics (Foley *et al.*, 2005). In addition to creating a clear contradiction between the supply and demand for soil and water resources, conversions between vegetation, water, and other ecological surfaces and construction land also have a negative impact on the environment. These effects include reduced evapotranspiration and worsened water quality, accelerated flow, and an increase in the urban heat island effect. One of the difficulties in today's urban climate and environment research is how to scientifically monitor, assess, and evaluate the consequences of urban heat islands. Global climate change is a result of urbanization on many different levels.

LST (Land Surface Temperature) is the temperature of the earth's surface that is in direct contact with the measuring device (Niclòs *et al* ., 2009). LST is the temperature at which solar heat and radiation are absorbed, reflected, and refracted by the surface of the earth's crust. The perfect forecast of LST is difficult because of changes in meteorological conditions and other human activities. LST is often estimated on a regional or global scale with satellite retrievals since in-situ measurements are constrained and LST has a relatively high geographical variability. LST, which is controlled by surface heat fluxes and plays a significant role in global climate change, rises rapidly as a result of urbanization. Near surface air temperature readings can be assessed based on the availability of large-scale satellite acquired LST data. According to recent studies, the percentage of people living in cities is predicted to rise to 65% by (2025) (UNFPA. 2007).

Remote sensing pictures that are multi-temporal and multi-resolution can give the fundamental information needed to analyze urban spatial data and the thermal environment. Prior research points to a substantial negative association between NDVI and LST, while NDVI varies significantly with the season (Maity *et al.*, 2020). According to Zha *et al.*, (2003) Normalized Difference Built-up Index (NDBI) is the linear combination of the middle infrared (MIR) band (1.55~ 1.75 m) and the near infrared band (0.76~ 0.90 m) used to extract urban built-up land. The human microenvironment is reflected in much research that links temperature to health (Gasparrini *et al.*,2015) because it affects how they evaluate the exposure-response relationship. Using remote sensing data to analyze the urban heat island has been a popular study direction (Wang *et al.*, 2016)

P-ISSN: 1996-983X
E-ISSN: 2960-1908
مجلة المخطط و التنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10

In this work, ArcGIS 10.8 software is used to compute the temperature at the land's surface (LST) from the years 2019-2022 and understand their link between LST, NDVI and NDBI and capability for mapping by LANDSAT-8 TIRS's.

Material and methods

Study area

The current study was conducted in Duhok City's urban regions (36.52.03 N; 42.59.34 E), in the northern Kurdistan Region of Iraq. The city is around 107 km2 in size and is located between 430 and 540 meters above sea level (asl) at (Fig.1). There are now 1,133,627 people living in the Duhok Governorate (NCCIRAQ, 2015). The city has a unique scenery since it is surrounded by two foothill chains: the Zawa Mountains on the south and the Bekher Mountains on the north. Duhok possesses a Mediterranean climate dry and hot in summer and cold and rainy in winter. The annual average rainfall is about 619.49 mm and the mean annual temperature is around 20.5 °C. The rainy season starts from October to May, while the rest months of the year are regarded as dry.

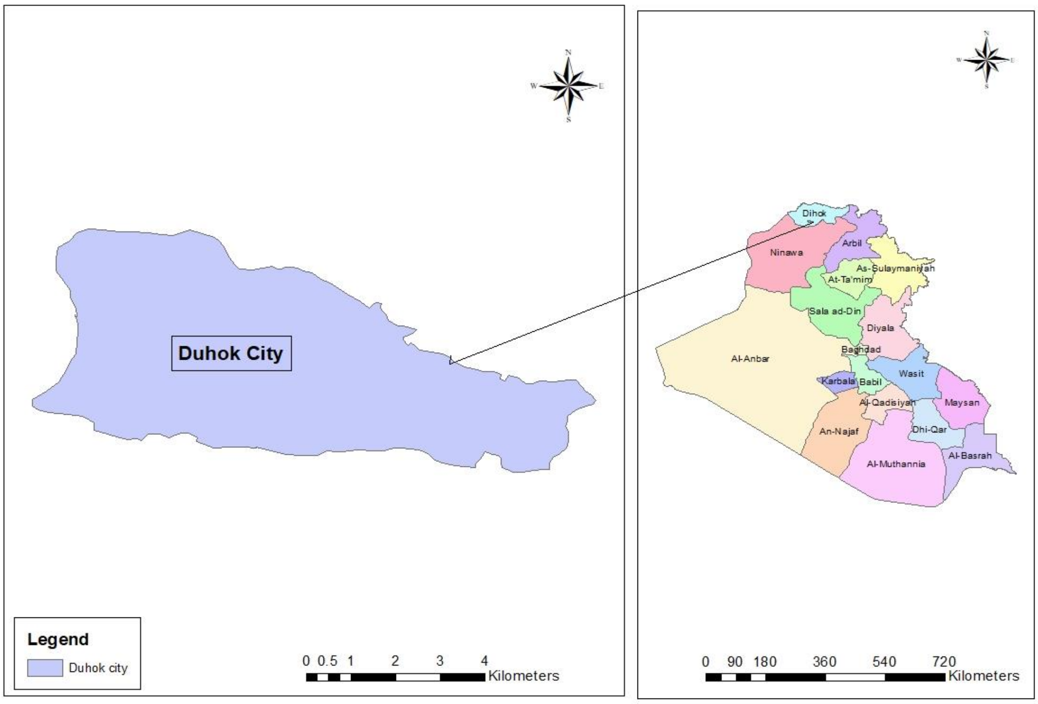


Figure 1 . The location of Duhok city

P-ISSN: 1996-983X
E-ISSN: 2960-1908

مجلة المخطط و التنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10

Data Resources and preprocessing

For this study, the United States Geological Survey (USGS, http://earthexplorer.usgs.gov) used photos from Landsat 8 OLI/TIRS taken on summer season in four years at 9 July 2019, 25 June 2020, 14 July 2021 and 9 July 2022. ArcGIS 10.8 and Microsoft Office 2019 were used by the writers. The scale of the map (1:46,800). The gray value or digit number (DN) of the multispectral bands, transformed into the reflectivity values of the sensor, is employed during the pre-processing of datasets.

Normalized difference vegetation index (NDVI)

The NDVI was used to determine the amount of healthy green cover. Its Normalized Difference Formula combined with the chlorophyll region of high reflection and absorption makes it effective throughout a wide range of words (Tan et al., 2010) by comparing the spectral properties of red and NIR waves.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Whereas Red is (Band 4) with a wavelength of (0.64-0.67 m) and NIR is (Band 5) with a wavelength of (0.85-0.88 m). The range of the NDVI index is from -1 to 1. It typically falls between 0.2 to 0.8 for green plants.

Normalized difference Building index (NDBI)

The NDBI formula is used to calculate the building density index, which is used to determine the density of buildings. Band 5 and Band 6 Landsat 8 imagery is used by NDBI. According to Govil *et al*.,(2019) using the NDBI formula

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$$

Where SWIR is Band 6 wavelength of (1.566- 1.652) The range of the NDBI value is from -1 to +1. Higher NDBI values indicate built-up regions, whereas lower values indicate water bodies. The vegetation NDBI value is low.

Land surface temperature (LST):

In order to extract LST from raw Landsat datasets, it is necessary to convert the thermal bands' DN values (Bands 10 and 11 in Landsat OLI/TIRS) to absolute radiance values first (Chander et al., 2009). Depending on the terrain, a spectral emissivity modification is done following the approach n(Sobrino *et al*., 2004). For the purpose of creating an LST map for all of the research locations, we used Landsat-8's pre-processed Band 10 data, which included top-of-atmosphere brightness temperature values expressed in Kelvin. The emissivity-rectified LST counts that indicated in Eq. 3. after converting the Brightness temperature data to Celsius (°C**).**

$$LST(°C) = \frac{T_B}{1 + (\lambda * T_B / \rho)\ Ln\varepsilon}$$

where TB = Landsat-8 Band 10 brightness temperature, λ = wavelength of emitted radiance (applied at 10.8 m, the center wavelength of Landsat-8 Band 10), ρ=h×c/σ (1.438 × 10−2 m K) σ = Boltzmann constant (1.38 *1023 J/K), h = Planck's constant (6.626* 1034 Js), and c = speed of light (2.998 *108 m/s); and ε is the land surface emissivity, calculated

$$\varepsilon = mPV + n$$

Where m= (εv−εs)−(1−εs) Fεv and n=εs+(1−εs) Fεv, where εs and εv are the corresponding emissivities of the soil and plants. We used the analysis for m(0.004) and n(0.986) by Sobrino et al. Applying this equation results in Pv, which stands for vegetation ratio as:

:

$$Pv = (\frac{NDVI - NDVI_{min}}{NDVI_{Max} - NDVI_{min}})^2$$

Where NDVI was calculated using Landsat-8's surface reflectance, as given in Eq (1).

Result and Discussion

The Landsat-8 OLI pictures were used to extract all of the parameters used in this work, including LST, NDVI, and NDBI. The NDVI maps created for the research region in 2019, 2020, 2021 and 2022 are displayed in Figure 2. Consistent geographical and temporal comparisons of vegetation conditions are

P-ISSN: 1996-983X
E-ISSN: 2960-1908

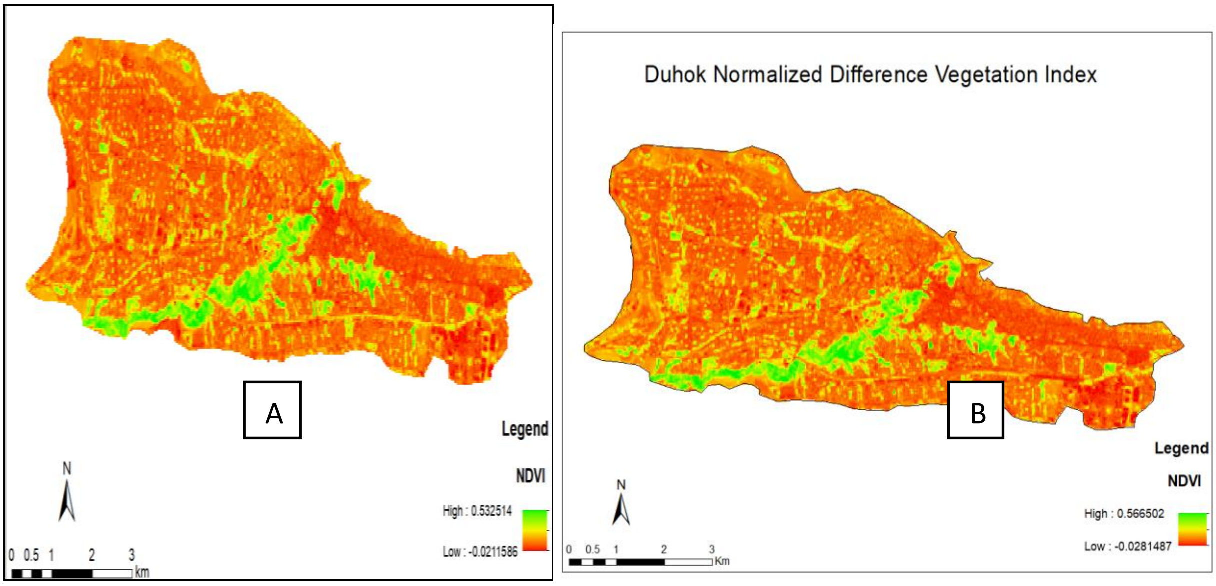
مجلة المخطط و التنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10

made possible by the NDVI maps. Consistent geographical and temporal comparisons of vegetation conditions are made possible by the NDVI maps. These maps are helpful for supporting phonological research, change detection, and biophysical interpretations by tracking the activity of terrestrial photosynthetic plants on Earth. Additionally, metropolitan areas are expanding globally, and in many nations, people are moving from rural regions to the more active metropolis in search of greater economic opportunities and educational opportunities. Many industries have been impacted by this problem, including the environment, agriculture, and transportation.

Figure 2 illustrate the ranged from minimum to maximum NDVI values which have was in the year 2019 ranged from 0.02 – 0.53 which referred to high NDVI, while in the year 2020 with the mean about 0.136 then decline to about 0.124 in the year 2022 as a result of this conversion of vegetative land to settlement, and most of vegetation density founded in the middle side of Duhok city around (Hishkarw) river and it was almost too few in other places.



P-ISSN: 1996-983X
E-ISSN: 2960-1908

مجلة المخطط و التنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10

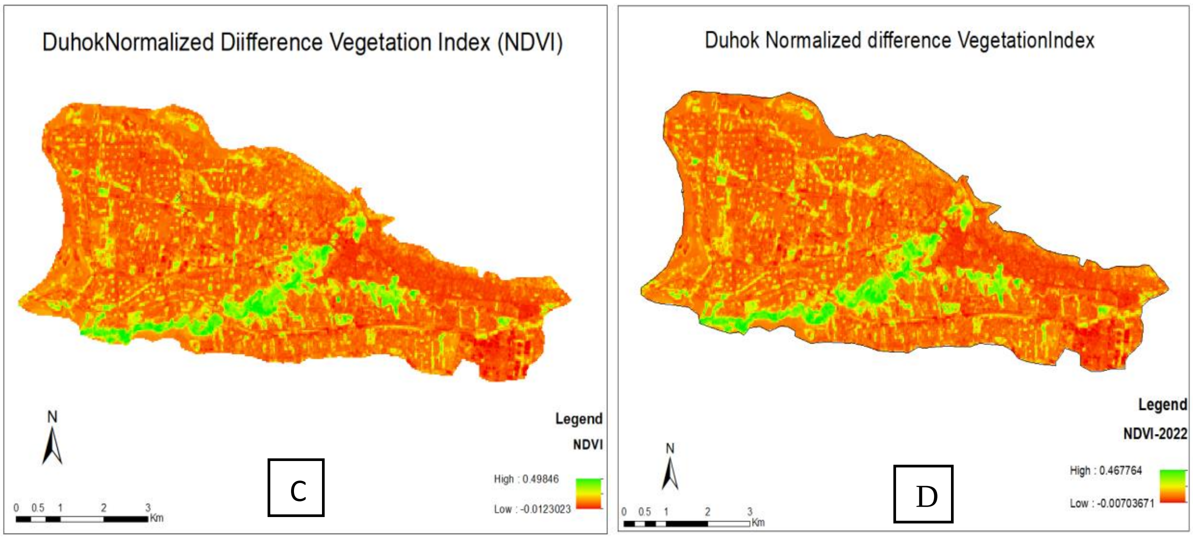
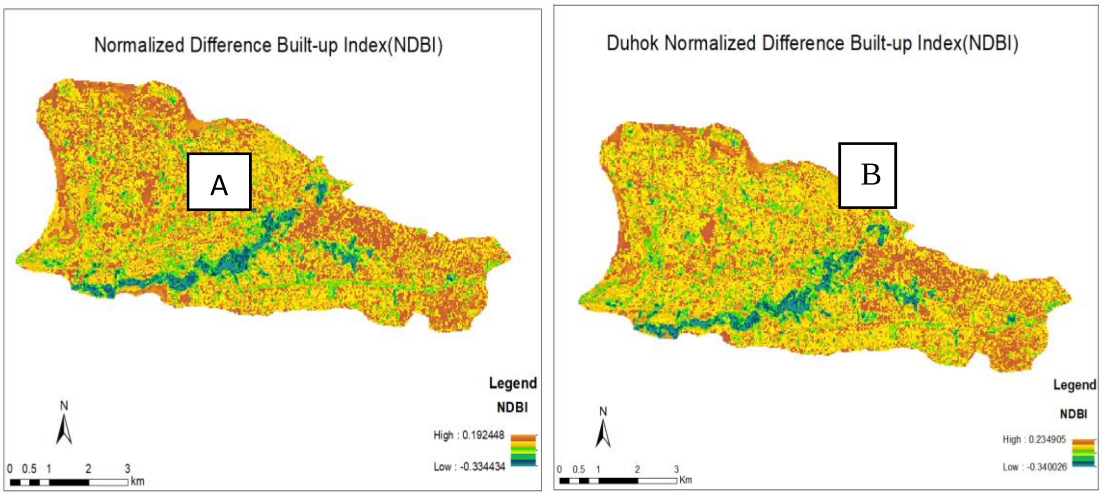
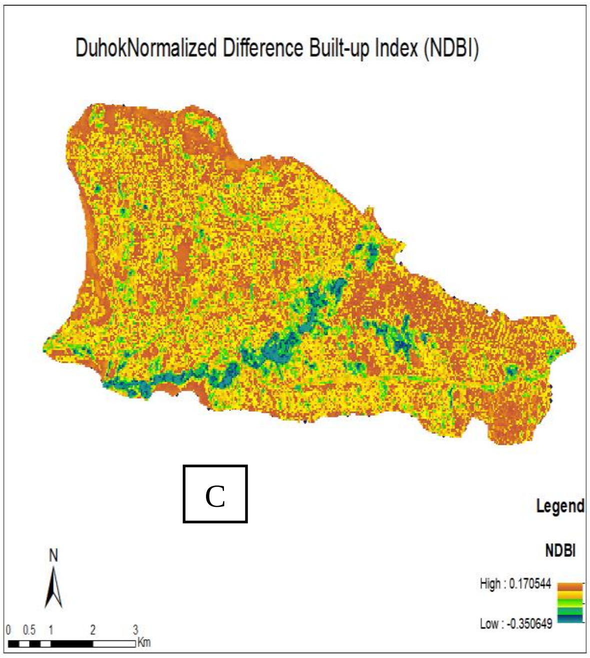


Figure (2) NDVI in Duhok city at years (A) 2019 (B) 2020 (C) 2021 (D) 2022

The NDBI maps exist in figure 3, in 2019 building density may be observed in the number of sparsely populated urban areas, which have an index value of 0 to 0.1 and are thus residential areas. While places that are not residential and have an index value of less than 0 may be found in the middle and middle east portion of Duhok city, which indicates the water body. On the other hand, compared to the year 2022 the NDBI ranged from -0.32 to 0.17 which indicated that most part of Duhok city changed to settlement area.



P-ISSN: 1996-983X
E-ISSN: 2960-1908
مجلة المخطط والتنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10



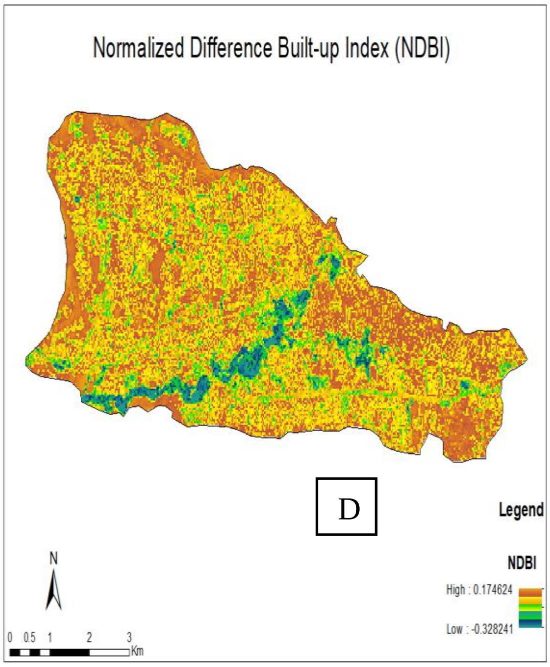


Figure (3) NDBI in Duhok city at years (A) 2019 (B) 2020 (C) 2021 (D) 2022

The land surface temperature obtained from satellite data represents the surface temperatures of each item inside a pixel, which may be made up of various land cover categories. LST maps of the research region in four years from 2019-2022 respectively were created using the equations mentioned above to analyze data from Landsat-8 thermal band 10 in ArcGIS 10.8. LST maps figure 4. Which indicated in the maps of Duhok city the ranges of the surface temperature get higher if we compare in four years in summer season that ranged from 29.28 ˚C – 34.39˚C to 43.65˚C -50.27 ˚C in 2019 then raised in 2020 and 2021 ranged from 32.1˚C - 50.9˚C to 33.07˚C - 52.3˚C respectively while decline a little a bit in the year 2022 ranged about 32.04˚C -47.78˚C.

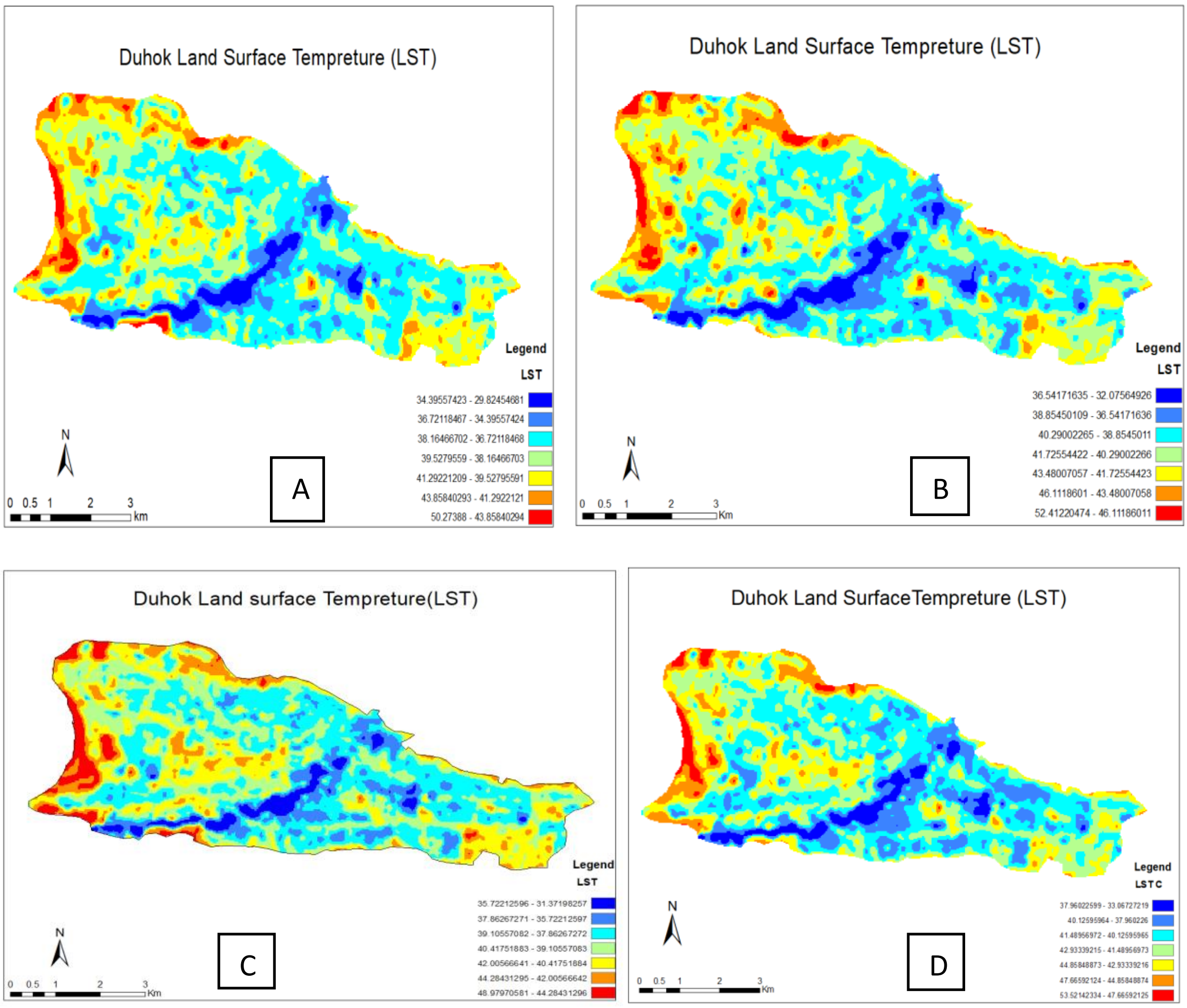


Figure (3) LST in Duhok city at years (A) 2019 (B) 2020 (C) 2021 (D) 2022

This study looked at the relationship with scatter plots between vegetation cover (as measured by the NDVI), urban density (as measured by the NBDI) and LST (surface temperature) during three time periods. The Figure(4) related to the linear relationship between LST and NDVI and NDBI in the year 2019 that show the positive correlation between LST and NDVI, whereas the negative correlation between the NDBI and NDVI and LST, that mean LST increases that as the environment is drier and dense. Areas with high LST values contrast with those with low NDVI values. There was very low correlation between NDBI and LST and also between NDVI and NDWI were (0.03). In order to regulate the climate and reduce the heat in metropolitan areas, it may be necessary to project LST into the near period. Based on this particular analysis, a variable is recommended to project LST in the research region as the NDVI prediction will be more accurate than the NDBI prediction.

P-ISSN: 1996-983X
E-ISSN: 2960-1908
مجلة المخطط و التنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10

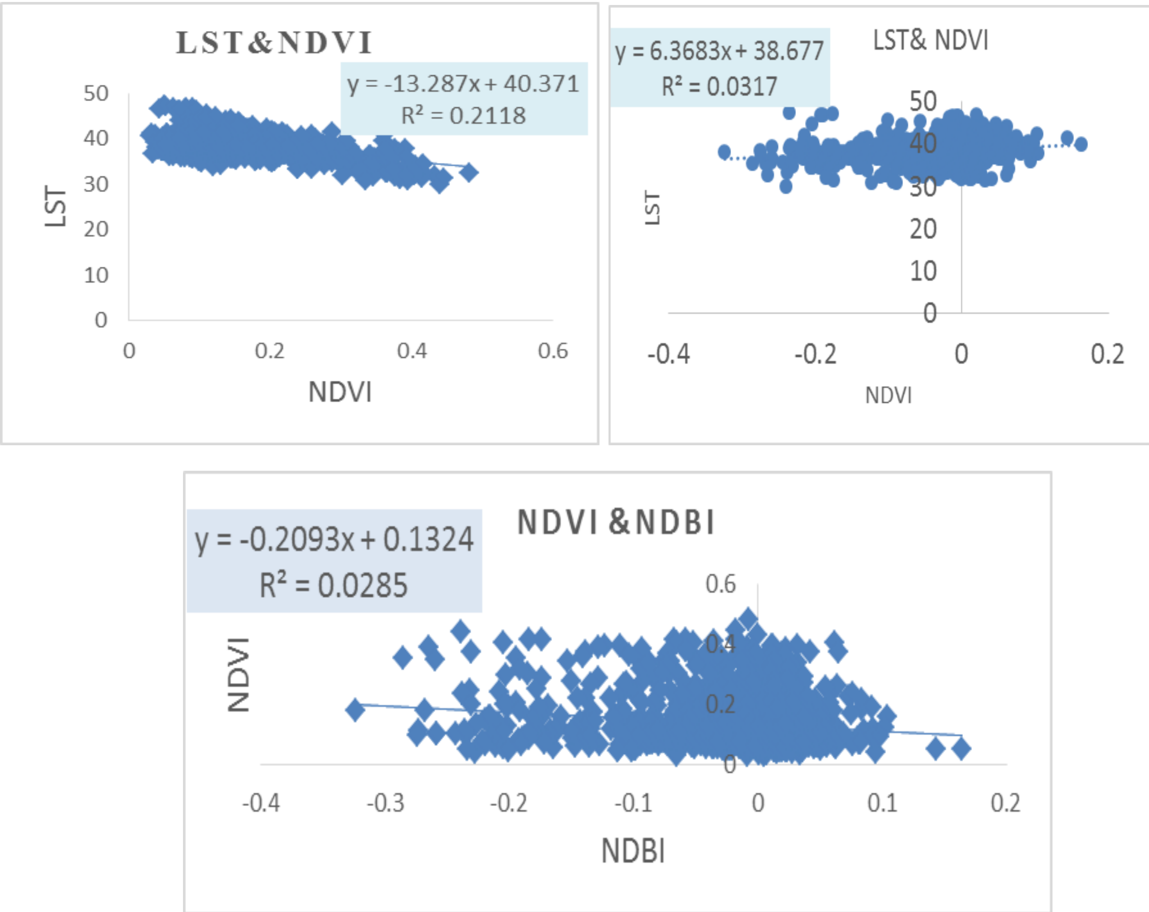


Figure (4) Scatter plot indices correlation LST, NDVI and NDBI in Duhok city at year 2019.

In the year 2020 the correlation between spectral indices and LST as found in the figure (5) There is a positive relationship between LST and NDVI and negative relationship between LST and NDBI and NDVI and NDBI. There was a very weak correlation between LST and NDBI and NDVI and NDBI with about 0.036 and 0.032 . Whereas the correlation between the LST and NDVI is about (0.59). In fact, the correlation is 0.4 larger than it was for the preceding period, which was 2019.

P-ISSN: 1996-983X
E-ISSN: 2960-1908

مجلة المخطط و التنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10

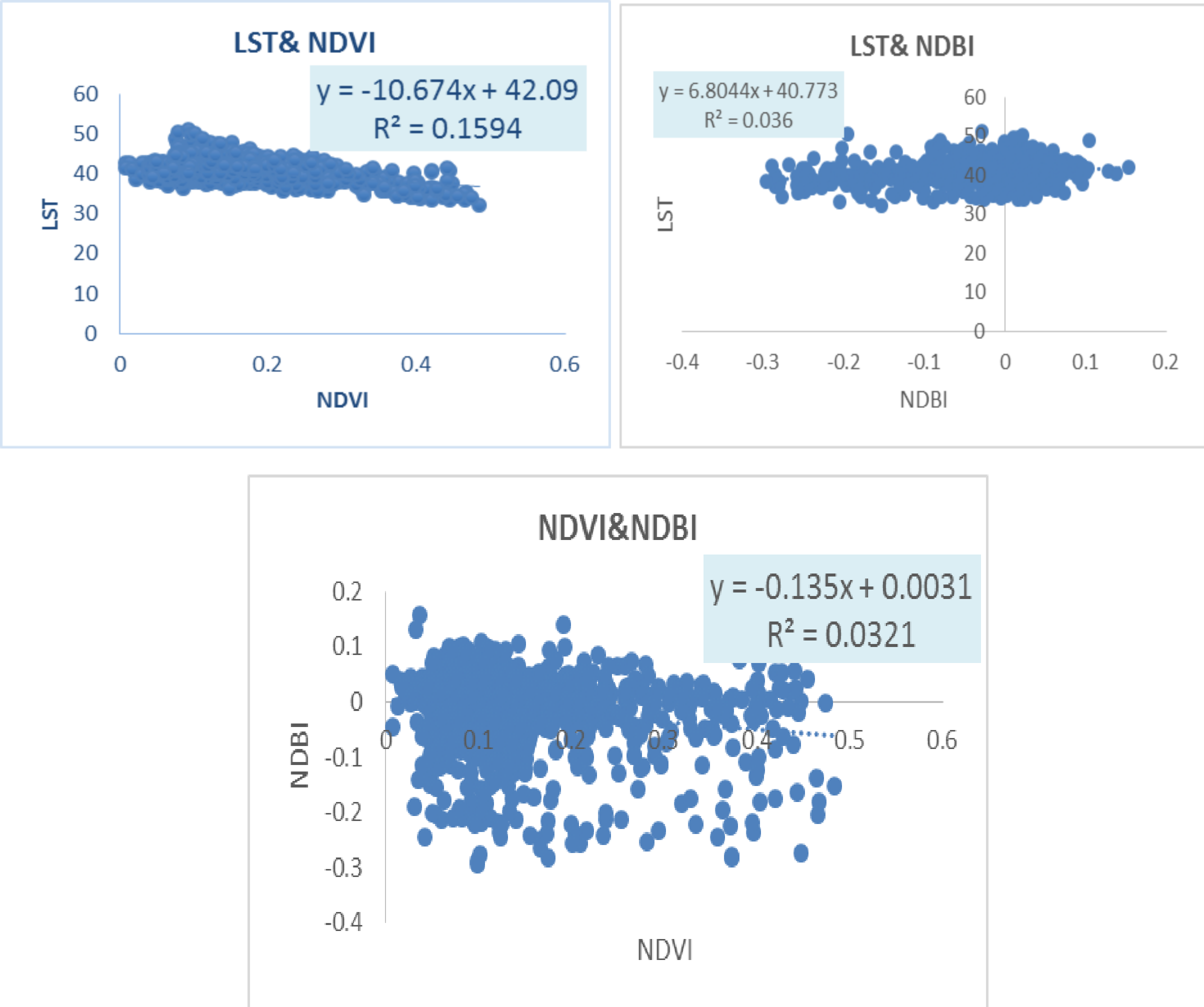


Figure (5) Scatter plot indices correlation LST, NDVI and NDBI in Duhok city at year 2020

The year 2021 received the same correlation study. At figure (6) The correlation between LST and NDBI and NDVI and NDBI was negative. On the other hand, the correlation between the LST and NDVI was positive with about 0.64. This referred to the relation between the LST and NDBI and NDVI and NDBI; those also agree with the outcomes for the years 2029 and 2020.

P-ISSN: 1996-983X
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مجلة المخطط والتنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10

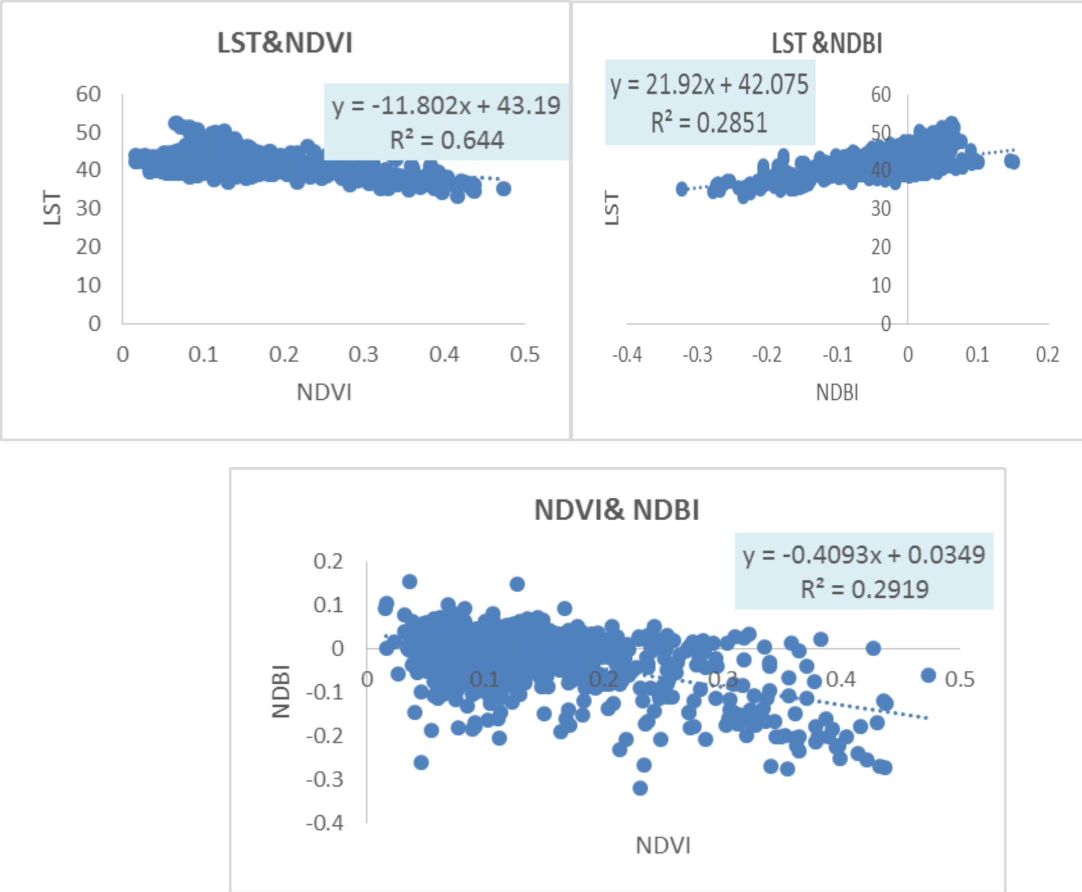


Figure (6) Scatter plot indices correlation LST, NDVI and NDBI in Duhok city at year 2021

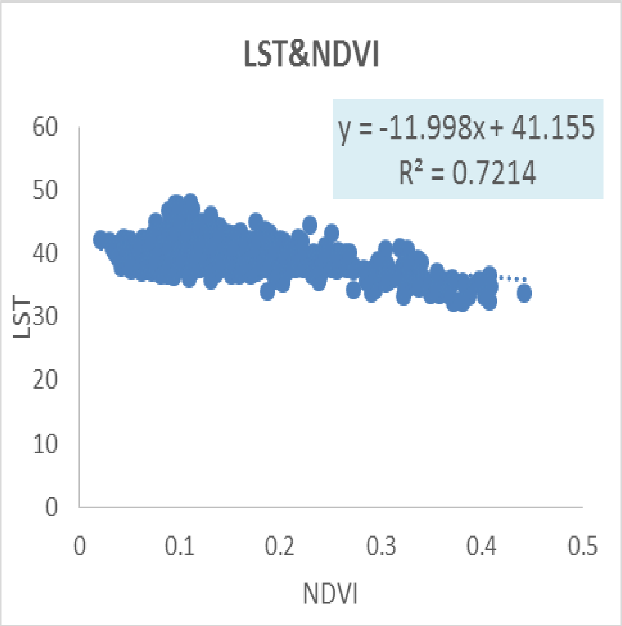
In the figure (7) The outcomes point to a different situation in the year 2022. The funding indicated a weak correlation between LST and NDBI nearly the same in the year 2020 and 2021 was about(0.3). Whereas the correlation between LST and NDVI is positive correlation with higher and all other previous years about (0.72). and a strong correlation between the NDVI and NDBI with about (0.8).

P-ISSN: 1996-983X
E-ISSN: 2960-1908

مجلة المخطط و التنمية

Journal of planner and development

Vol 28 Issue 1 2023/5/10



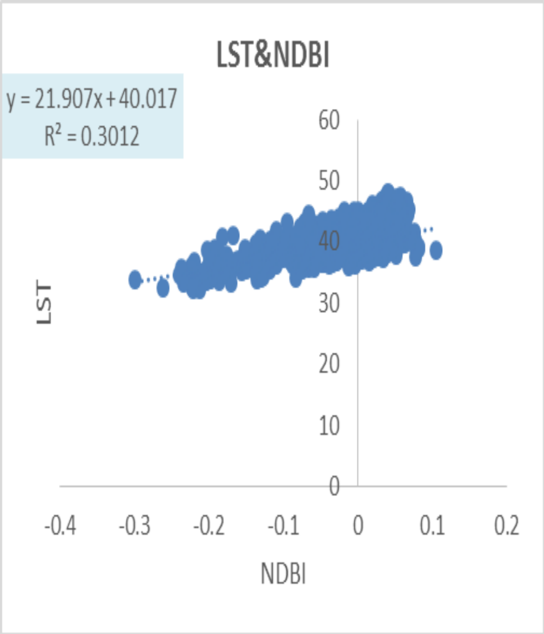
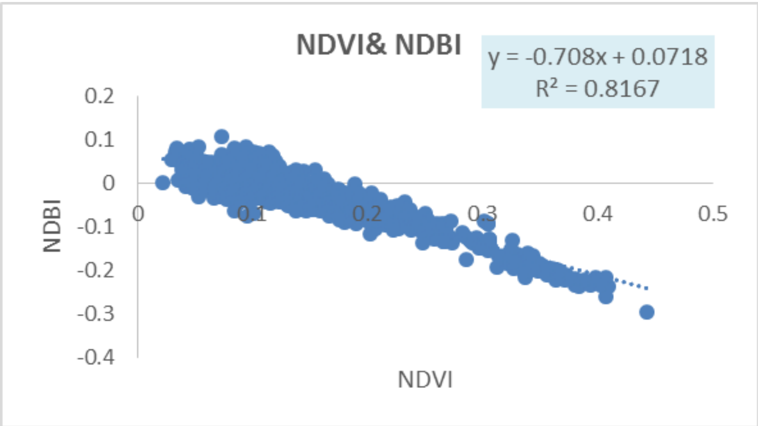


Figure (7) Scatter plot indices correlation LST, NDVI and NDBI in Duhok city at year 2022



P-ISSN: 1996-983X
E-ISSN: 2960-1908
مجلة المخطط والتنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10

Conclusion

ArcGIS 10.8 and Landsat 8 were used to determine an area's LST, NDVI, and NDBI in Duhok City. Estimation of the relationship between those parameters from the years 2019- 2022. Based on LST studies, built-up and bare surfaces have higher surface temperatures, whereas healthy vegetated regions have lower temperatures. The maximum NDVI 0.53, 0.56 0.50 and 0.47 in four years respectively. The built-up index is being described using satellite data from Bands 6 and 5.The maximum NDBI in each year was 0.19, 0.23, 0.17 , 0.174 respectively. The Maximum LST value 47 , 51 , 52 and 48 in four years. The significant correlation found between LST & NDVI R^2=0.64 and R^2 =0.72 in the year 2021 and 2022, whereas the higher negative correlation found in the year 2022 was about R^2 = 0.82 between NDVI and NDBI. Healthy green vegetation decreases surface temperature. Thus, it can be inferred that NDBI may be used to reliably inform urban planning and construction in addition to analyzing and forecasting LST and drawing the urban heat island effect in any location.

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P-ISSN: 1996-983X
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مجلة المخطط و التنمية
Journal of planner and development
Vol 28 Issue 1 2023/5/10

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