LU/LC changes and its impacts on land surface temperature in Erbil City in the Kurdistan Region of Iraq

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ABSTRACT

Today, several factors, including the destruction of urban green cover and the uncontrolled increase of environmental pollutants in urban areas, lead to the confinement of solar radiation energy and the occurrence of the phenomenon of the urban heat island. It has dangerous consequences including the transmission of air pollution and toxic dispersed particles. The main purpose of this study is to identify the relationship between land use land cover and land surface temperature from 2000 to 2020. In this regard, Landsat 5 - TM and Landsat 8 - OLI_TIRS satellite images from 2000, 2011, and 2020 were used. In this study, after applying the necessary corrections and teaching the images, changes in land-use and land cover LU/LC changes and the type of changes were identified. The study result showed that built-up land has increased by 24.5 percent between 2000 and 2020. NDVI vegetation index was calculated and then LST was calculated using thermal bands, by used GIS10.8 and RS. The results showed that during 20 years, the temperature of Erbil has increased by 4C° degrees. about the correlation between NDVI and LST, the highest correlation was recorded in 2011 when $R^2 = 0.8552$ This means that the higher the NDVI ratio, the lower the LST ratio.

KEY WORDS: Landsat5-TM, Landsat8-OLI_TIRS, LU/LC, Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST).

1. INTRODUCTION

In the last decade, the sudden increase in world population is one of the most significant problems that can normally be predicted. By 2050, the world's population will reach 9.8 billion (Walker, 2016) According to the latest research in the middle of the 21st century, in 2050, it is predicted that most of the world's population will live in urban areas with a ratio of 66%, this percentage is high (Nations, 2017) This increase in population in urban areas directly affects the expansion of urban areas (Jamei, Rajagopalan and Sun, 2019) and global warming is one of the major problems facing the human race and the environment (Amuzu *et al.*, 2018) The most important factor in this problem is the expansion of cities (Hussain, Bhalla and Palria, 2014).

Since the second half of the twentieth century, urbanization as one of the most important human phenomena has affected the world. (Singh, Kikon and Verma, 2017) According to current studies, one of the most important problems in urban areas is rising ground temperatures. (Kumar, Bhaskar and Padmakumari, 2012) UHI Urban Heat Island has the effect of surface temperature in urban areas and its significant difference with the surrounding environment and the reasons are different. Among these factors are natural and human factors that change the amount of surface temperature in urban areas by changing land use and land cover LU/LC.(Emmanuel and Krüger, 2012)(Emmanuel and Krüger, 2012)

In the last few years, accurate Land Surface Temperature (LST) has become more important because it has a direct impact on human life in the city (Weng, 2009). Most of the changes that land us/land cover LU/LC have a clear

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impact on LST. This is because of airborne particles, plants, building paint, roads, roofs, type of materials ... etc. (Sahana, Dutta and Sajjad, 2019)(Chudnovsky, Ben-Dor and Saaroni, 2004). In general, There are more reasons to influence urban LST by the scale of areas around the urban. Because those phenomena that exist in urban areas have several characteristics; they receive more energy with less time, while dissipating this energy faster (Shahfahad *et al.*, 2020). What is necessary here is to point out that it is not only the horizontal changes of LU/LC that affect the LST but also the vertical changes that occur in the expansion of urban land that has a negative effect on the LST (Bonafoni and Keeratikasikorn, 2018). This building acts as an obstacle in the direction of the winds which causes the change of the wind direction (Saha *et al.*, 2020).

LST is very important in many fields because the spatio-temporal variations of LST are essential for fields such as physics and biology. (El-Zeiny and Effat, 2017) (Mohammed Hamud, Mobarak Prince and Zulhaidi Shafri, 2019). It should be noted that a negative or positive change in LST causes a delay in cycles (nitrogen, water, biochemistry). (Anastasios Polydoros, 2018) (Nimish, Bharath and Lalitha, 2020). This is not only reflected in that area but in the whole planet.(Jin *et al.*, 2015) (Nimish, Bharath and Lalitha, 2020). LST is the first step for many scientific studies such as the ratio of absolute particles in the air, CO2 in sludge, hydrology(Nimish, Bharath and Lalitha, 2020) (Setturu, 2013) For example, many studies have shown that the area with the highest LST ratio has the highest CO2 ratio (Arista, Saraswati and Wibowo, 2020), Analysis of the relationships between LAST and NDVI and NDVI varies from time to time but Strong and opposite relationships are observed between LST and NDVI(Kumari *et al.*, 2018) (Saha *et al.*, 2020), So the higher the NDVI ratio, the lower the LST ratio,(Phan, Kappas and Tran, 2018) (V.V., B.V. and T.R., 2017).The correlation between LST and NDBI is straightforward, This means that the higher the NDBI, the higher the LST. This is because NDVI takes longer to receive and distribute energy than NDBI (Nega, Hailu and Fetene, 2019)(Kumari *et al.*, 2018).

Today, Remote Sensing (RS) enable the study of LST and help to understand energy flows in urban areas (Pinakkattu, Gurugnanam and Bairavi, 2018). Over the past few decades, satellite imagery has become a valuable tool for studying various aspects of the thermal island phenomenon, humid urban area. Remote sensing is a useful tool for quantifying land surface temperature in response to changes in LC/LU. (Orhan and Yakar, 2016) Multi-time satellite images can be used to detect changes in land cover and land use and successive changes in LST (El-Zeiny and Effat, 2017); (Butt *et al.*, 2015) GIS is one of the advances in these technologies that are used to achieve accurate and precise goals.(Rahaman *et al.*, 2020). There are many study researchers He et al (2019)., Zhao et al (2017), El-Zeiny and Effat (2017), Jamei et al. (2019), Bonafoni and Keeratikasikorn, (2018), Karakus (2019) applied remote sensing images to create land use and surface temperature maps and to monitor land use changes. The target of this study is to use remote sensing and GIS to detect land use/ land cover and their effect on land surface temperature.

2.MATERIALS AND METHODS

2.1Review Stage

Erbil city is one of the largest cities in the Kurdistan Region of Iraq. It is also considered the capital of this region. This city located between two provinces which are Duhok Province in the west and Soleimani Province in the east of the city, in latitude 36°08′ N to 36°14′ N, and longitude 43°57′ E to 44°03′ E (Figure 1). The city is 426 meters above sea level (Rasul *et al.*, 2015) and the total area of the city is14.873.68 square meters (Hussein,

Kovács and Tobak, 2017) but the study area is only 43247 hectares. The city has grown tremendously in the last two decades so that the population of this city has reached 1,530,722 people by 2015, the growth rate of this population was 2.9%. (Rasul, Balzter and Smith, 2017). The city has semi-arid and continental characteristics in terms of climate (Mustafa and Szydłowski, 2020) but if we look at this city by e Köppen climate classification, we come to the conclusion that this city has semi-arid and semi-warm climate characteristics (BSh). The annual temperature of this city is 21.85 C° but in summer the temperature reaches 49 C°. (Rasul, Balzter and Smith, 2015). The Land use of this city is mostly residential, which are mostly made of concrete and block for the construction of these houses. So there are several parks in the city, the largest of which is Sami Abdul Rahman Park.

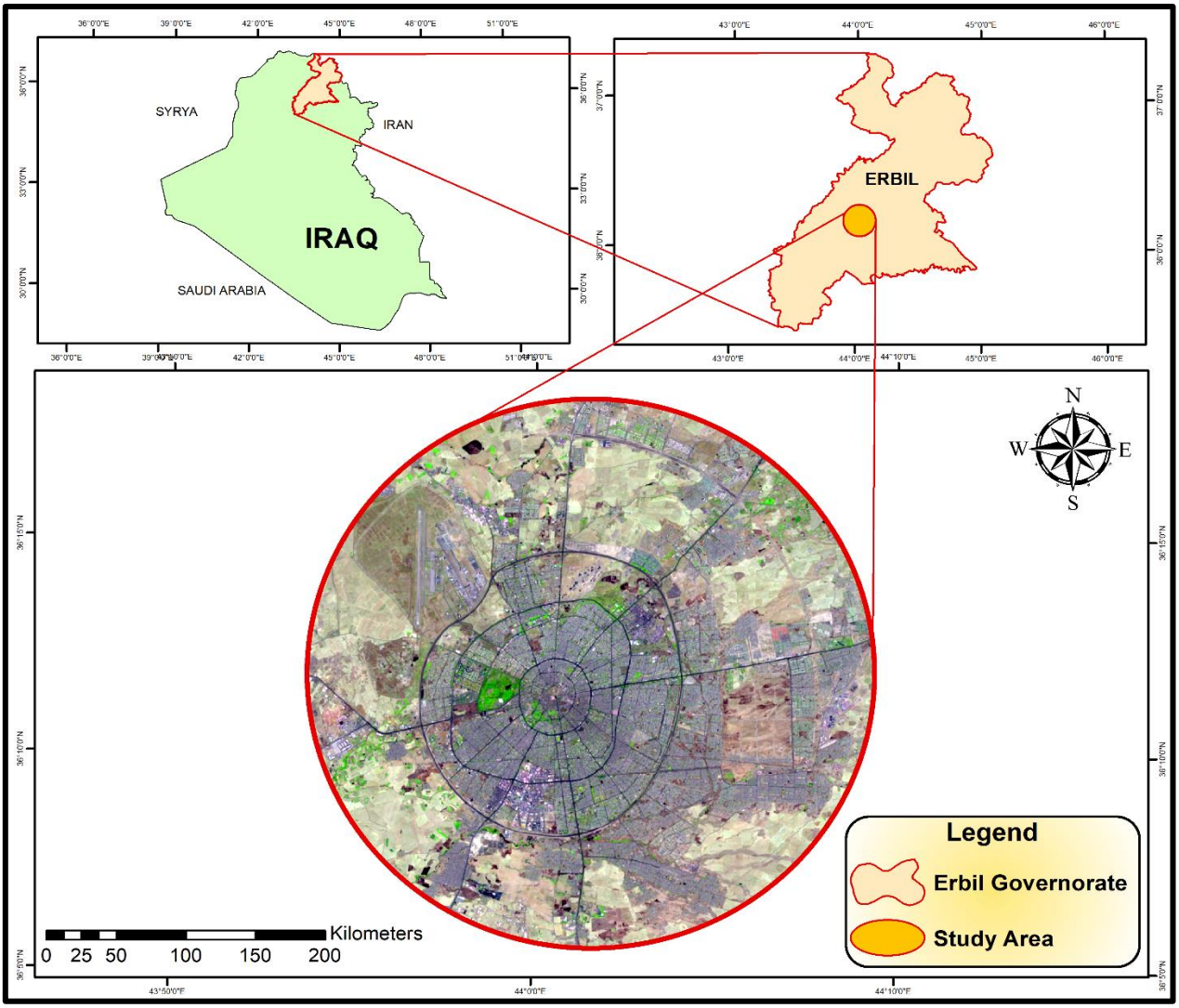


Figure 1. location of the study area, Duhok City.

2.2Used Data:

In this study, to investigate the LST concerning land use and land cover, the data used include two categories. The first category is the Landsat satellite image that downloaded from the united states Geological Survey (USGS) at three different times. The first image is Landsat 5 – TM is dated 2000-6-27, second Landsat is dated 2011-6-10, and the third Landsat 8 – OLI_TIRS dated 2020-06-18. The spatial resolution of used data is 30m, 100m, and 120m (Table 1). The use of

images in summer is due to the lack of clouds and high intensity of thermal infrared in solar radiation. the second category is vector data like master plan of Erbil city and boundary of province and country.

Details Of Landsat 5-Tm Satellite Images			
BAND NUMBER	**Wavelength (micrometers)**	**Resolution (meters)**	**Band Name**
Band 1	0.45-0.52	30	Blue
Band 2	0.52-0.60	30	Green
Band 3	0.63-0.69	30	Red
Band 4	0.76-0.90	30	Near IR
Band 5	1.55-1.75	30	Mid IR
Band 6	10.40-12.50	120 (30)	Thermal
Band 7	2.08-2.35	30	Mid IR
Details Of Landsat 8-OLI Satellite Images			
BAND NUMBER	**Wavelength**	**Resolution**	**Band Name**
Band 1	0.43-0.45	30	Coastal aerosol
Band 2	0.45-0.51	30	Blue
Band 3	0.53-0.59	30	Green
Band 4	0.64-0.67	30	Red
Band 5	0.85-0.88	30	Near Infrared (NIR)
Band 6	1.57-1.65	30	SWIR 1
Band 7	2.11-2.29	30	SWIR 2
Band 8	0.50-0.68	15	Panchromatic
Band 9	1.36-1.38	30	Cirrus
Band 10	10.6-11.19	100	Thermal Infrared (TIRS) 1
Band 11	11.50-12.51	100	Thermal Infrared (TIRS) 2

Source: www.landsat.gsfc.nasa.gov/landsat-data-continuity-mission.

2.3Methodology:

In order to achieve a correct and accurate result this research has been used Geography Information System GIS 10.8 and Erdas Imagine software. Processes and analysis have been used in this research are downloading satellite imagery, subset and classification then preparing the LU/LC map, land surface temperature map. After that, we examined and analyzed the relationships between land surface

temperature, NDVI, and different uses by calculating linear regression relationships. In the framework below, all the stages of this research are mentioned .(figure 2)

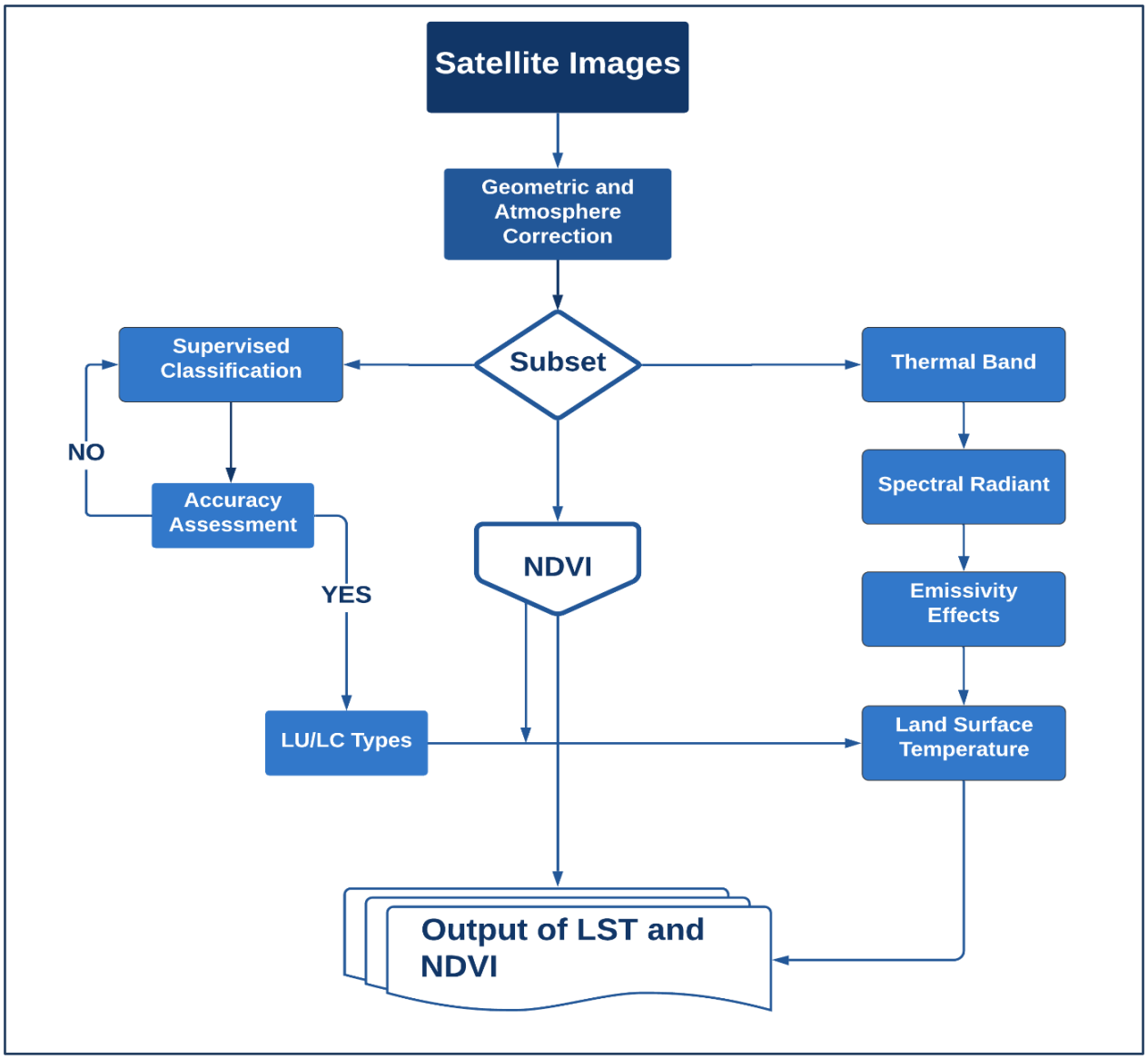


Figure 2: flow chart showing used methodology

2.3.1. Image Classification and Accuracy Assessment

Satellite imagery and supervised classification were used to identify land use changes in the study area. Land use maps were prepared for 2000, 2011 and 2020. this research focuses on that types of LU/LC (built-up land, vegetation land, and barren land) (Table 2). In the supervised classification for each phenomenon or LU/LC, a number of pixels are selected as educational examples to be used to classify information in the next steps. In this classification, the Maximum Likelihood Method (MLH) was used, this method is more accurate than other classification methods (El-Zeiny and Effat, 2017). This study selected a 40 training sample of 40 pixels for each land cover class in the study area (Khan *et al.*, 2019). After the digitizing trained site of pixels, statistical characteristics of each type of LU/LC are calculated. It is noted here that MLH is the most important basis for statistical parameters (Olorunfemi *et al.*, 2020). Afterward, three city classes obtained that they are built-up areas, vegetation land, and barren

land. To evaluate the classification accuracy, a field survey was conducted in the study area.

Table 2 : types of land use and land cover

Types of LU/LC	Description
BUILT-UP LAND	Residential, industrial, commercial areas, areas under construction, roads and streets
VEGETATION LAND	Types of vegetation include urban green spaces and parks and agricultural lands
BARREN LAND	Areas with little vegetation in the form of bare ground, including those that have never been used before.

2.3.2.Computation of NDVI:

NDVI is a simple and practical indicator that measures the condition of vegetation in an area (Gandhi *et al.*, 2015)(Park *et al.*, 2014)(Malik, Shukla and Mishra, 2019) which helps analyzes of areas that are vegetated or non-vegetated (Sara Afrasiabi, Mahdi Panahi, 2013). This index is calculated based on two bands, nir-infrared and red, which is calculated based on this formula was used:

$$NDVI = \frac{NIRum - Redum}{NIRum + Redum}$$

In this method, the ratio of the amplitude of the changes and the NDVI values are from -1 to +1. For this purpose, NIR infrared band and RED band 3, 4 or 4 and 5 satellite images of TM and OLI were divided into uncovered and vegetated classes. However, LST is highly correlated with vegetation range (Yue *et al.*, 2007). NDVI could be used to examines and estimates the relationship between vegetation and LST (Marzban, Sodoudi and Preusker, 2018)(Khan *et al.*, 2019). In general, the relationship between LST and NDVI related to spatial and temporal variations (Julien and Sobrino, 2009)(Karnieli *et al.*, 2010)

2.3.3.Computation Of Land Surface Temperature (LST)

A separate Mono-window algorithm is used to estimate land surface temperature. An important feature of this algorithm is the elimination of atmospheric effects (Rongali, Keshari and Gosain, 2018). Therefore, it widely uses several sensors in retrieving the surface diffusion capability like thermal infrared with spatial resolution 100m and 120m (S. and C.R., 2016). Extraction of the surface temperature using band 6 thermal TM satellite and thermal band 10 OLI satellite. Used formula is:

$$L(\lambda) = gain * DN + offset$$

This can also be stated as

$$L(\lambda) = (LMAX - LMIN)/255 \times DN + LMI$$

where

L(λ) = Spectral radiance w ·sr−1 ·m−3

LMIN = 1.238 (Spectral radiance of DN value 1)

LMAX = 15.600 (Spectral radiance of DN value 255)

DN = Digital Number

The next step is to transform Spectral Radiance to Temperature in Kelvin with the following formula:

TB = K2

$$TB = \frac{K_2}{IN\frac{K_1}{R} + 1}$$

K1 = Calibration Constant 1 (607.76)

K2 = Calibration Constant 2 (1260.56)

R = Radiance values W/m2 SRμm

In the final step, Kelvin is converted to Celsius with the following formula:

$$TB = TB - 273$$

TB = Surface Temperature ◦C

3.Results and Discussion

3.1.Land Use / Land Cover Maps:

Land use maps for 2000, 2011, and 2020 were prepared using the Maximum Likelihood Method, and to ensure the performance of land classification. There is evaluated the accuracy assessment of LU/LC maps. For this purpose, this Research evaluated the prepared maps using the maximum probability method using the kappa coefficient and overall accuracy. According to the results, all maps are very accurate in classification and are within an acceptable range, **Table 3.** According to the results of the Kappa index of 2000, 2011, and 2020, which were 89%, 85.8%, and 84.7%, respectively.

Table 3: accuracy assessment of land use/cover between 2000, 2011 and 2020

YEARS	2000	2011	2020
Overall accuracy %	94.7	92.7	92.5
Kappa index %	89	85.8	84.7

The results of the area and changes of each land use land cover LU/LC class are shown in Table 4 and Figure 3. In the year 2000, 10.12% of the area was Built-up land, and 9.12% was vegetation land. And 80.75% are bare lands, It has the largest area in 2000 with 34923.2 hectares, The second area was built-up land with the area of 4377.15 hectares and the lowest area was vegetation land with 3947.22 hectares. The area of all three types of the LU/LC together is 43247 hectares. During 2011, the results show significant differences (Table 4). The most changes occured in the Built-up Land, which has increased from 4377.15 hectares to 13013.6 hectares by 19.97 percent. And bare land with a decrease of 13%, unfortunately, it should be noted that vegetation land decreased 7% while the area of 3947.22 hectares of vegetated area has been reduced to 963.63 hectares, between 2000 and 2011. In 2020, urban land has continued to increase compared to 2011 which increased by 4.53 percent, its area is 14976.6 hectares and with a ratio of 34.63 percent. Again, the vegetation land has the lowest area of 1204.86 hectares, but optimistically, it has increased slightly by 0.557 percent. It should be noted that the city's land has increased by 24.5 percent from 4377.15 hectares to 14976.6 hectares between 2000 and 2020. Important factors that can lead to increasing the urban land use of Arbil city was the city was selected in 2003 as the capital of the Kurdistan region and second, politics and economy are two important reasons for the increase of this city (Ibrahim, Mushatat and Abdelmonem, 2015). And this increase gives the shape of a circle to the land of the city. This returns to the shadow of the topographic and geological factors of the city of Erbil on the garden plain (DR. NISHAN S.M, 2018)

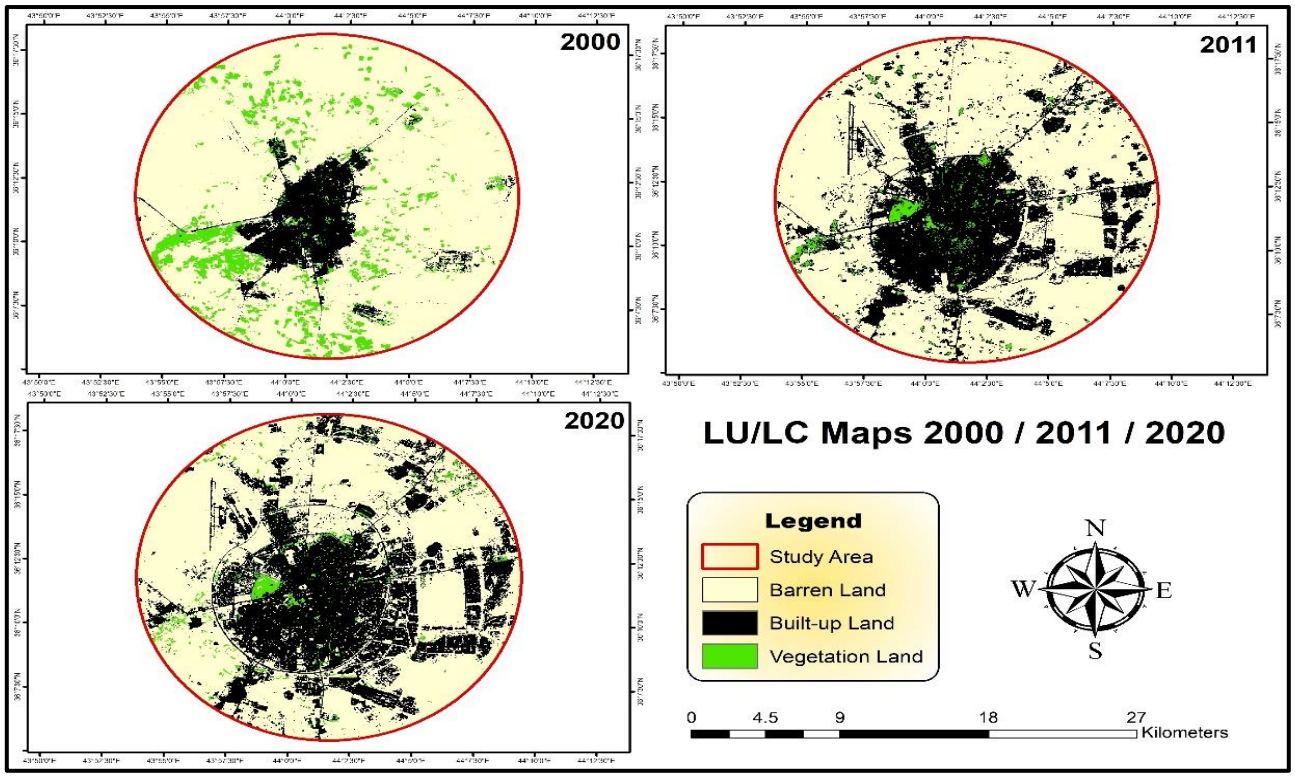


Figure 3. supervised classification of land use/land cover

Table 4: show the quantity of land use/land cover

class name	area hectares 2000	area % 2000	area hectares 2011	area % 2011	area hectares 2020	area % 2020
Barren land	34923.2	80.75	29270.3	67.68	27066.3	**62.58**
Vegetation	3947.22	9.12	963.63	2.22	1204.86	**2.78**
Build-up land	4377.15	10.12	13013.6	30.09	14976.6	**34.63**
total	43247	100	43247	100	43247	**100**

3.2.Land Surface Temperature Retrieval

Land Surface Temperature maps extracted for years 2000, 2011 and 2020, during the period of 20 years are shown in Figure 4. In general, during every three years used in this study, the temperature of the barren land is higher than the temperature of the built-up land of the city. Based on Figure (4) the lowest temperature in 2000 was 32 C° and the highest temperature was 51 C°. It means there was a 19 C° difference between the lowest and highest temperature. But in the image of 2011, the highest temperature was 48 C° and the lowest temperature was 29 C°. In 2020 the value of the highest temperature was 55 and the lowest one was 33 C°. Urban expansion from 2000 to 2020 leads to growth low LST area, espessially, in the east and the south part of the city.

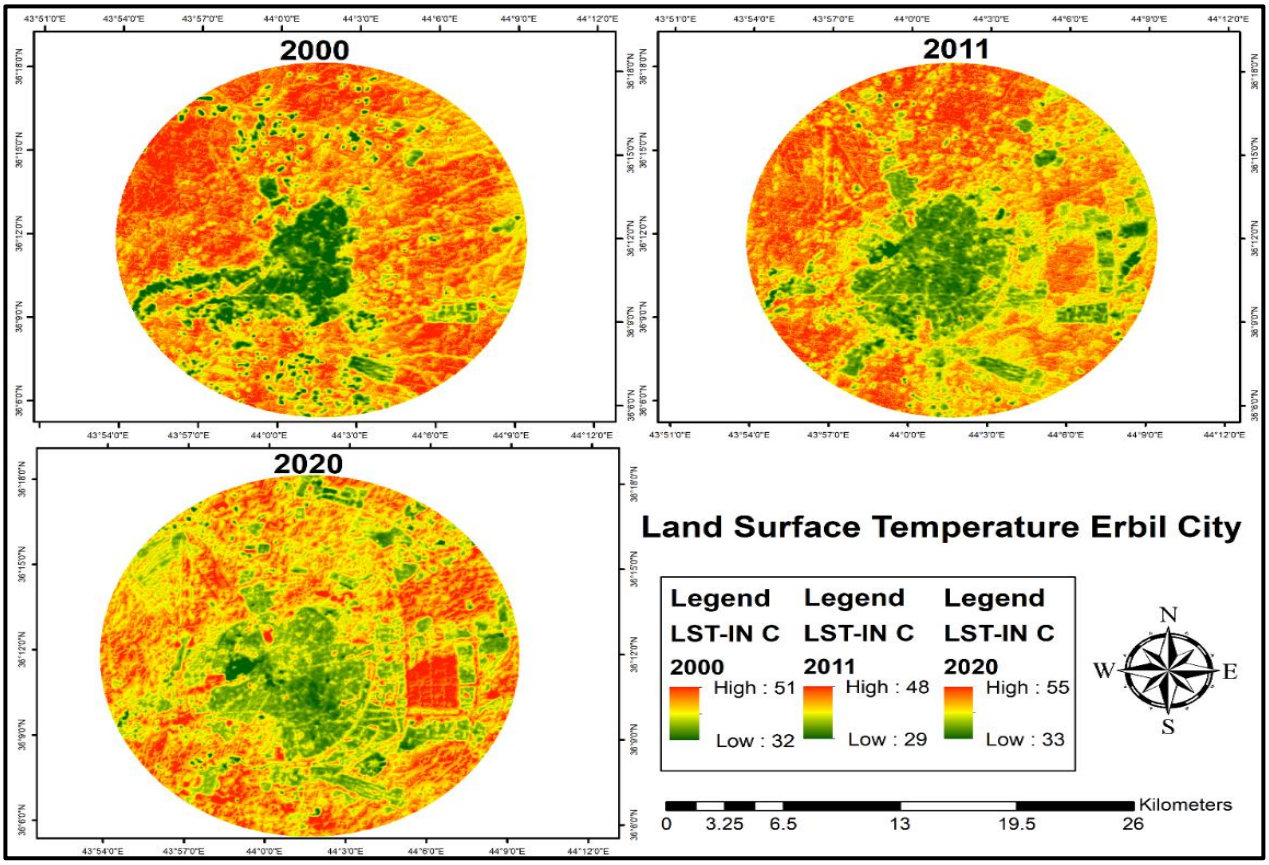


Figure 4. land surface temperature map extract in thermal band of Landsat.

In order to point out all the details of the geographical areas of the LST, we analysis figures 5, 6, and 7 for the years 2010, 2011, and 2020. In 2000, areas with temperatures between 48 C° and 51 C° were clearly seen in large areas of east and west of the city center, such as Charchra, Karezan, Gulan2, Zilan and Hawlery New . In the east, areas are S-Abdulrahman Park, Parlieman and Dream City. Also some areas located in the south such as Zanko 2 and Roshanbiry (Figure 5), but it seems that the areas where there was a high temperature in the north were scattered, such as north of Ainkawa, Naz and east of Kany. All of these areas were the phrase of barren lands. Areas whose LST was low, in other words, their land surface temperature was between 34 C° and 38 C°.bird-shaped form is seen in several different areas, such as areas Raperin, Setaqan, Mufty, Andazyaran and Shady. Those areas whose temperature is recorded between 39 C° and 40 C°, it can be seen from north to west, and very small areas can be seen in the southeast.

About 2011 Figure 6 extracted from LST shows several different results from 2000. The most prominent sight is the S-Abdulrahman Park area. In 2000, the LST of this area was between 47 C° and 48 C°, but in 2011 this degree decreased by 30 C° and 35 C°, the lowest land surface temperature LST in 2011 was recorded only in this area. The LST of 28 C° is mostly seen in the middle of the city center and also the LST is 39 C°can be seen in most of the areas, especially in the north of Gelawezh and Aikawa middle of Roshanbiry. All those areas whose temperature was between 36 and 38 are called built-up land of the city, areas whose temperature was between 43 C°and 46 C° some areas are seen especially in newly urbanized areas, such as Hawlery New, some part of Gelawezh and

Roshanahnbiry, Serbesty and Twraq which included wide areas of barren lands.

In 2020 (Figure 7), the region has the lowest temperature (LST), it is the same region that had the lowest temperature in 2011, in other words, S-Abdulrahman Park the LST was between 34 C° and 40 C° is the lowest LST recorded in 2020. Each of the areas Mamostayan 1 And 2, Mufty, Chnar, Badawe, Saidawa and Xabat their LST were between 41 C° and 42 C°, while in 2011 the temperature of those areas between 36 C° and 37 C°. Temperatures of 43 C° have been recorded in Rizgary 1 and 2, Azady 1 and 2, Nawroz, Serweran and Shorsh. In 2010-2011 those areas were barren land but in 2020, these areas saw heterogeneous temperatures, this means that these areas are transformed from barren lands to urban lands. Temperatures 46 C° was found in Safee2 and Peshesazy bashur areas and scattered in each of the regions of Twraq, Zilan, Perlieman and Zagros.

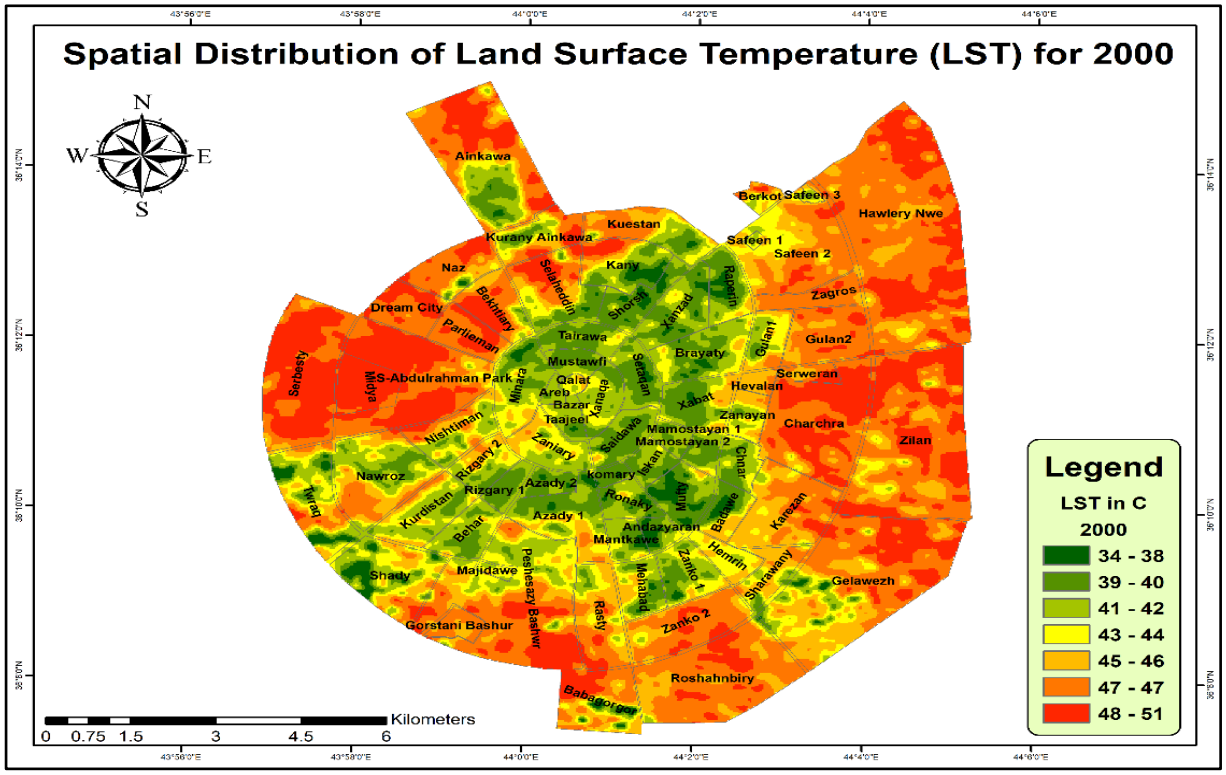


Figure 5. Spatial distribution of land surface temperature of 2000.

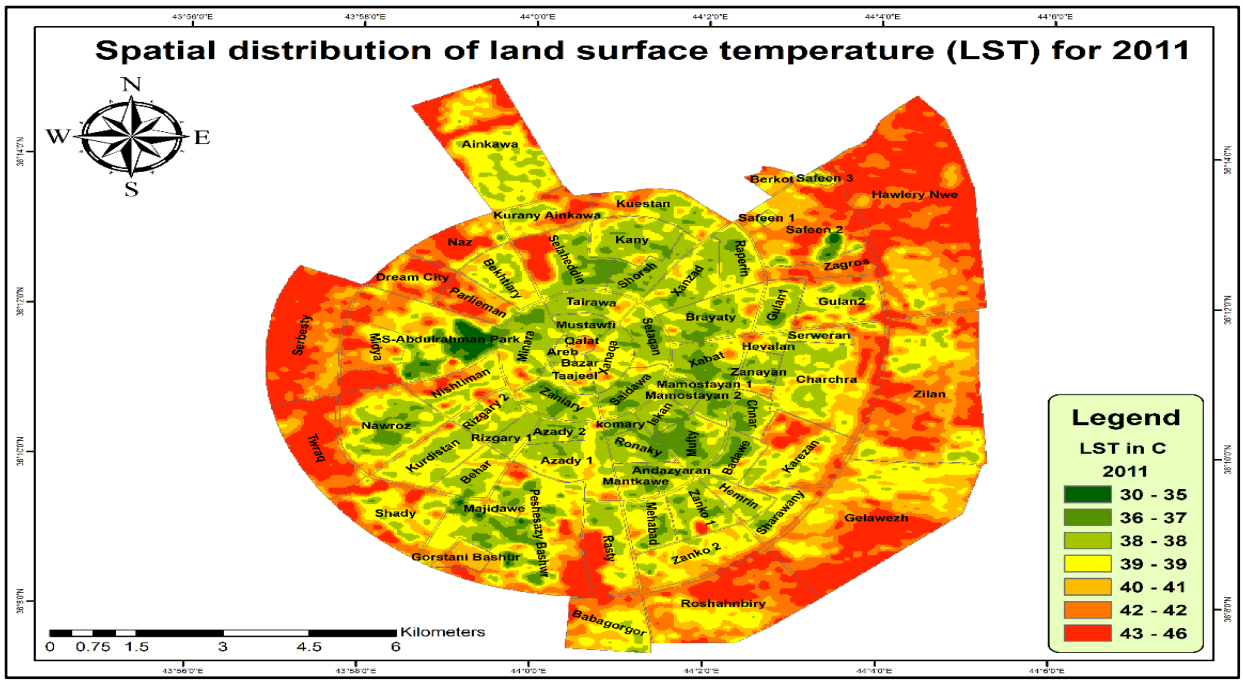


Figure 6. Spatial distribution of land surface temperature of 2011.

3.3. Relationship Between LST and NDVI:

Many studies have found that the higher the area of vegetation assosiated with the lower the temperature of the land, in other words, that as the increase of vegetation the temperature of the land decreases. According to the NDVI map, a combination of 0.39, 0.75 and 0.51 is the highest ratio recorded for 2000, 2011 and 2020 (Figure 8). In 2000, NDVI was scattered in the study area, but in 2011 and 2020 it was more concentrated in one area, which is S-Abdulrahman Park, but this does not mean that it is not seen in other areas.

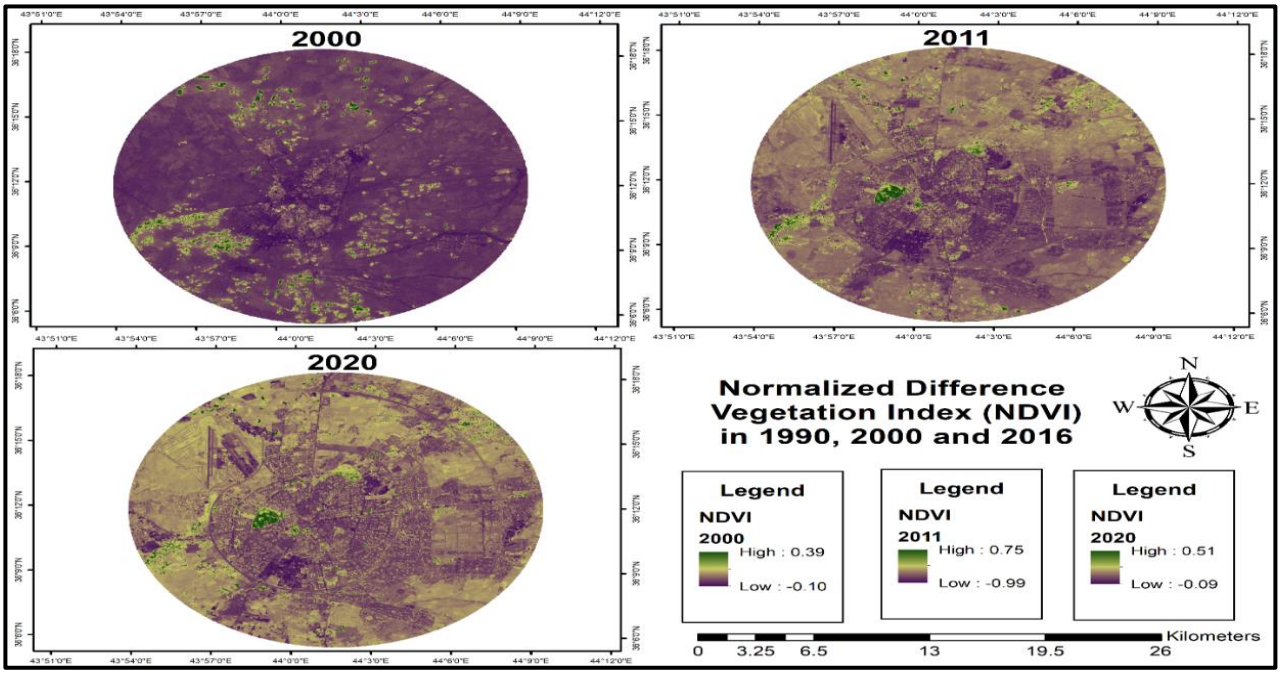
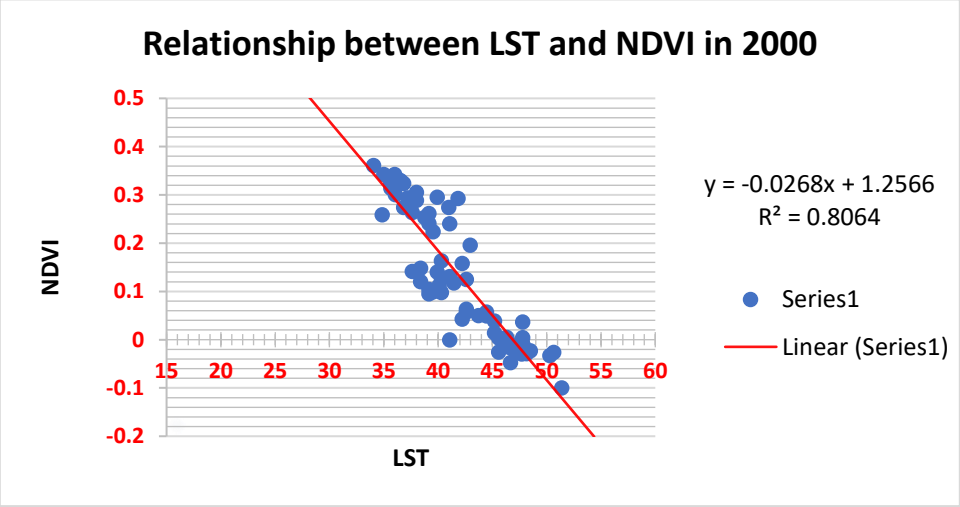
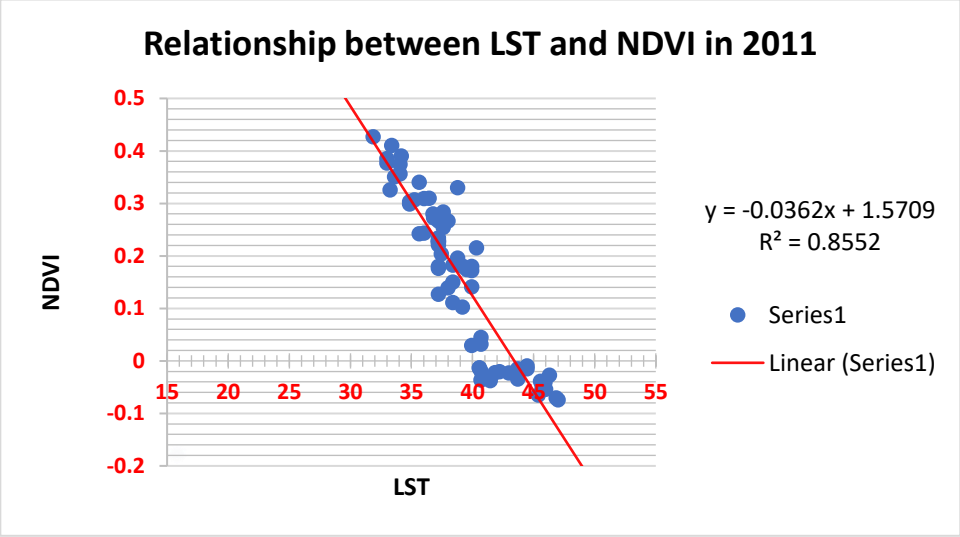


Figure 8. Normalized Difference Vegetation Index (NDVI) in 2000, 2011, and 2020.

In order to better investigate and analyze the relationship between LST and NDVI, the number of sample points was randomly selected throughout the city Erbil. According to the values of these points, there is a strong and firm relationship between NDVI and LST (Figure 9), The results show a negative relationship between normalized difference vegetation index and land surface temperature. For 2000, the R^2 was -0.8064, which is a very strong correlation and inverse type. The highest correlation was recorded in 2011 with R^2 = 0.8552. For 2020, the R^2 was 0.7815 and it considered the lowest correlation.





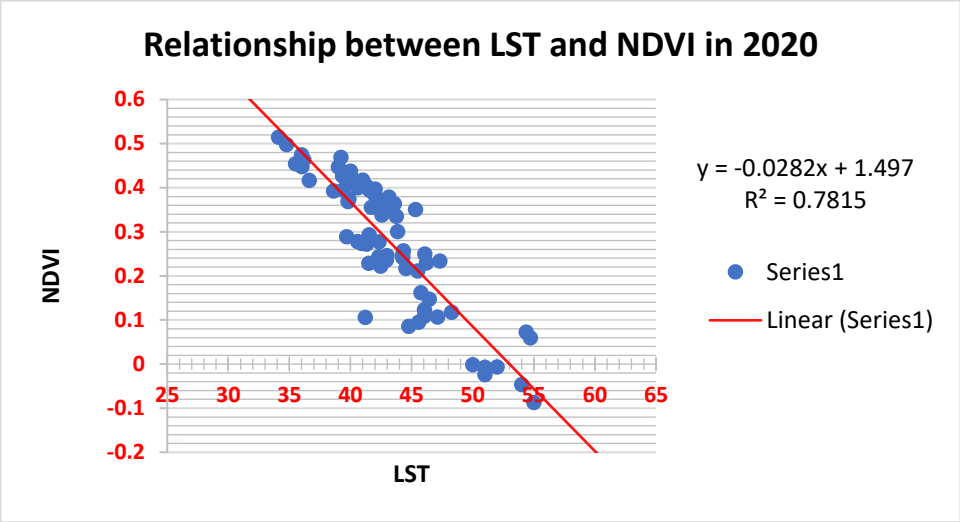


Figure 9. Relationship between NDVI and LST in the period of the study (2000, 2011 to 2020)

4.CONCLUSION:

Urbanization is creating an urban heat island (UHI) around the world that can pose a threat to human health and the environment. The urban heat island is an important issue in urban ecology that should be studied by examining the LST of the earth. In the present study, the effect of LU/LC changes on land surface temperature and in this regard monitoring of LU/LC changes in Erbil the Maximum Likelihood Method (MLH) model has been used for this purpose. The decreasing trend of vegetation land from 2000 to 2020 was about 2742.36 hectares for built-up and also in this regard barren lands decreased by 18.17%. And the built-up land of the city has increased by 24.51 percent from 4377.15 hectares to 14976.6 hectares, the trend of expanding has taken a circular shape to ensure the performance of land classification, the kappa coefficient, and overall accuracy of images in 2000 was 89%. Also, the results of surface temperature generally show that the temperature of built-up lands is lower than the temperature of barren lands located around the city due to the time taken of images. In addition, the spatial distribution of LST most changes visible area. This research has achieved that there is a very strong correlation between LST and NDVI. The results of this study and knowledge of land surface temperature for each land use can be a great help to urban managers in planning and managing urban land temperature and show the importance of urban green space development in reducing land surface temperature.

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