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Assessment of urbanization and different land use and land cover types on urban heat islands in growing cities, a case study: Tabriz, Iran

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Abstract

In this study, Landsat ETM+ and OLI images from 1984 to 2013 were selected to examine the relationship between land surface temperature and land use pattern in Tabriz, and to investigate the impact of land use changes on the urban heat islands. First, the mono-window algorithm was utilized to retrieve land surface temperature from thermal band of Landsat images. The zonal statistic was then carried out to evaluate the area proportion of land use classes in each LST category. Finally, the urban thermal characteristic was analyzed by investigating the relationships between the land surface temperature and land use types. The results suggest that the process of urbanization in Tabriz has significant effects on the surface temperature.

1. Introduction

Temperatures are gradually increasing globally due to a changing climate and have serious impacts on the health of human beings and other animal and plant species (Rinner and Hassain, 2011).

Urban heat island is a phenomenon caused by the increase of urbanization and air pollution. The city growth has changed the nature of surface reducing the presence of vegetation, with building structures and materials trapping solar radiation during the day, determining a significant temperature, differences between urban and rural areas (Bonafoni et al. 2016). Urban Heat Island, defined as the rise in temperature of any man-made area, result in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area's nearby natural landscape. When heat is radiated from surfaces of various land uses along with the presence of meteorological parameters such as wind speed and direction, an Urban Heat Island (UHI) can form (Taha et al. 2002). Beside high temperature, the thermal properties of land uses are playing significant role in producing heat islands (Streutker, 2003). When a land cover of buildings and roads replaces green space, the thermal, radiative, moisture and aerodynamic properties of the surface and the atmosphere are altered. In addition, the height of buildings and the way in which they are arranged affects the rate of escape of the sun's energy at night absorbed during the day by building materials. The result is that urban areas cool at a much slower rate than rural areas at night, thus maintaining comparatively higher air temperatures. Elevated temperatures from urban heat islands, particularly during the summer, can affect a community's environment and quality of life. While some impacts may be beneficial, such as lengthening the plant-growing season, the majority of them are negative. These impacts include: Increased energy consumption; Elevated emissions of air pollutants and greenhouse gases; Compromised human health and comfort; Impaired water quality

By using remote sensing techniques and data processing methodologies land surface temperature both in local and global scale can be acquired in order to analyze the relationship between temperatures, land use and land cover during different temporal intervals. In the present study satellite images of Landsat 7 ETM+ and Landsat 8 are used at 6 different dates from 1984 to 2013. The main objective is to examine the relationship between surface temperature and urban morphology and to interpret these relationships in terms of heat island processes and finally suggest some solution in order to make adjustment in UHI.

The Tabriz is the central city of Eastern Azerbaijan Province in Iran. Tabriz is Located in the Quru River valley between the long ridge of the volcanic cones of the Sahand and Eynali mountains (Figure 1).

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Tabriz is located in the coordinates of 38.0962° north latitudes and 46.2738° east longitudes with elevation ranges between 1,350 and 1,600 metres above sea level. The valley opens up into a plain that gently slopes down to the eastern shores of Lake Urmia, 60 kilometres (37 miles) to the west, with cold winters and temperate summers; the city is considered as summer resort (Tabriz, 2023).

2. Method

Two main datasets used in this study are: land use polygons of study area and remotely sensed thermal images. The land use data were obtained from Tabriz University, remote sensing laboratory. The dataset contained 62 types of land uses and Figure 1 shows the distribution of different land uses in Tabriz.

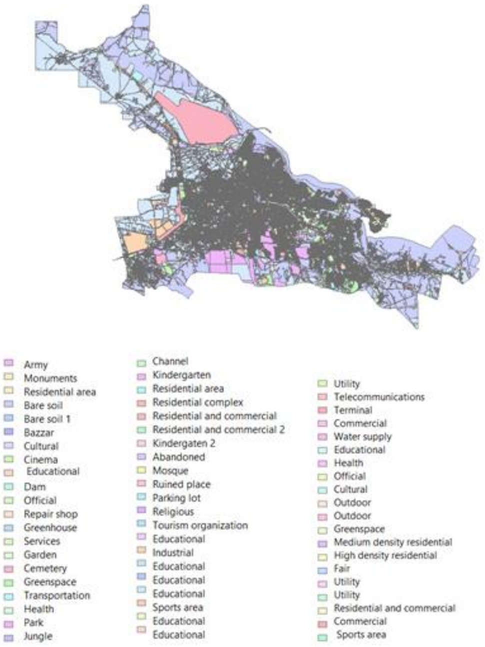

Figure 1. Distribution of land use categories in the city of Tabriz.

The satellite images were acquired from U.S. Geological survey's Earth Explorer database (http://earthexplorer.usgs.gov) including 5 Landsat 7 ETM+ and one Landsat 8 OLI images. The images were georectified to a Universal Transverse Mercator (UTM) coordinate system, using World Geodetic System (WGS) 1984 datum, assigned to Path 168 Row 34. Data set consists of six Landsat images belonging to years 1984,1990,2000, 2006,2011 and 2013 summer seasons, hence it is possible to evaluate the LST conditions in hot days (Table 1). Landsat 7 has 7 spectral bands with spatial resolution of 30 meters. Band 6 of Landsat 7 is thermal infrared band with 60 meters resolution but it can be resampled to 30 meters. Landsat OLI have 9 spectral band with 30 m spatial resolution for band 1-7 and 9, 1 panchromatic band with spatial resolution of 15 m for band 8 and 2infrared thermal bands with spatial resolution of 1oo m for band 10 and 11.

Table 1. Used data

Landsat	Date
7 ETM+	1984-08-27
7 ETM+	1990-08-28
7 ETM+	2000-08-23
7 ETM+	2006-08-24
7 ETM+	2011-08-22
8 TIRS	2013-08-27

In order to have accurate LST retrieval, estimation of land surface emissivity is important. Among lots of methods that have been proposed to obtain LSE drives NDVI threshold method proposed by Valor and Caselles (1996), is the most widely used method (Shi and Zhang, 2017).

$$P_V = [(NDVI - NDVI_{soil})/(NDVI_{veg} - NDVI_{soil})] \quad (1)$$

The NDVI is the normalized differential vegetation index; the $NDVI_{soil}$ and $NDVI_{veg}$ are set as empirical values of 0.05 and 0.7, respectively.

$$\varepsilon = P_V R_V \varepsilon_V + (1 - P_V) R_m \varepsilon_m + d_\varepsilon \quad (2)$$

Where ε is ground emissivity; ε_V *and* ε_m are emissivity of vegetation and building surface, respectively, set as empirical values of 0.986 and 0.970; d_ε is interaction of thermal radiation vegetation and building surface; R_V and R_m are temperature ratios of vegetation and building surfaces, calculated by the empirical equations:

$$R_V = 0.9332 + 0.0585 P_V \quad (3)$$

$$R_m = 0.9886 + 0.1287 P_V \quad (4)$$

By combination of equations (2) and (4), the ground emissivity can be estimated:

$$\varepsilon = 0.9589 + 0.086 P_V - 0.0671 {P_V}^2 \quad (5)$$

Ground emissivity of the study area was calculated by ENVI software using the above mentioned formulas.

2.1. Derivation of LST from Landsat 7 ETM+ and Landsat 8 TIRS

The land surface temperature (LST) was derived from Landsat 7 thermal band (band 6) and Landsat 8 TIRS thermal band (band 10) with the spatial resolution of 60 m and 100m, respectively.

First, the DN values were converted to spectral radiance by using the reflectance calibration process provided by ENVI program for all images and their metadata provided in the file with MTL extension.

The second step was to transform spectral radiance to at-sensor brightness temperature under the assumption of the uniform emissivity, using the following formula (Luo and Peng, 2016):

$$T_b = \frac{k_2}{\ln\left({}^{k_1}/_{L_\lambda} + 1\right)}$$

Where k_1 and k_2 are calibration constant. For Landsat 7 ETM+ k_1=666.09 k_2= 1282.71 mW cm^{-2} sr^{-1} µm^{-1}

As a final step the surface temperature was calculated by the following formula;

$$T_s = \frac{T_b}{\varepsilon^{0.25}}$$

After completing the calculation part, the LST image map of the study area was created (Figure 2). Figure 3, showed the mean, maximum and minimum LST of the study area in different years.

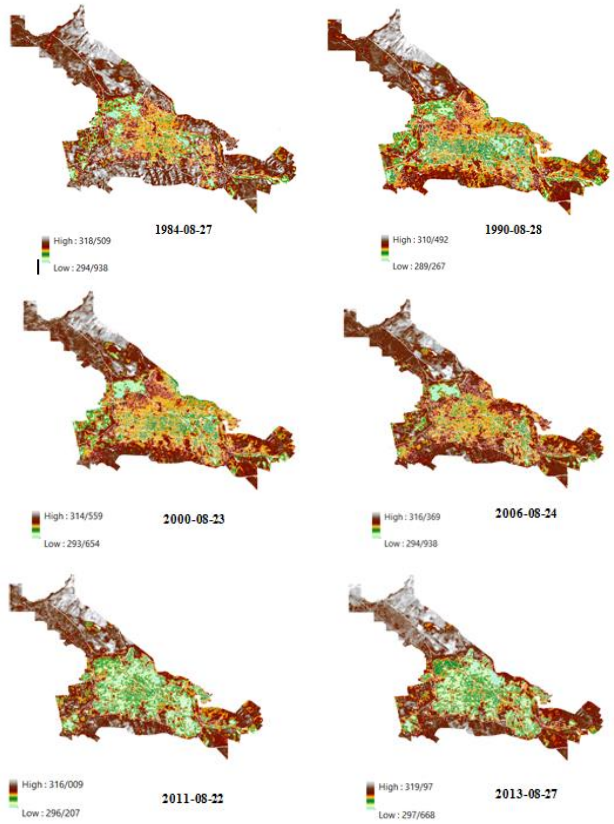

Figure 2. LST retrieval image map of Tabriz.

3. Results

3.1 Calculation of zonal statistics

After processing the Landsat images by ENVI software to get the land surface temperature, ArcGIS was put into use in order to identify tepmerature differences between land uses and also to assess the association between land use and land temperature. The thermal image was loaded in Arc GIS, and to get the detailed information about the land surface temperature of the study area, zonal statistics method was carried out. Zonal statistics, summerizes the values of the rasters within the zone of another dataset (either raster or vector) and reports the results in a table. The land use layer was used to define zonal boundries to obtain the mean surface temperature for each land use polygon. Zonal statistics on a thermal remote sensing image for the City of Tabriz revealed statistically significant differences between high average temperatures for commercial and resource/industrial land.

3.2 Calculation of NDVI

In this study, NDVI was used to present the relationship between LST and vegetation by linear regression correlation (Figure 3).

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

Where;

NIR and RED are the reflectance in the near infrared and red bands respectively.

NDVI due to its simple calculation is largely used for the vegetation studies in a regional as well as global level. It is always advisable to combine the NDVI along with other parameters to get better results (Sruthi and Aslam, 2015).

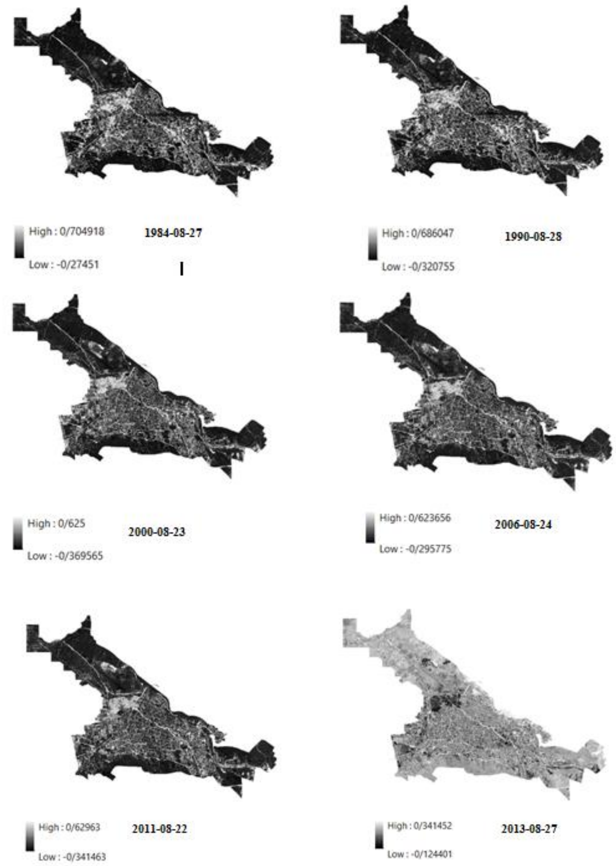

Figure 3: Normalized difference vegetation index (NDVI) of Tabriz.

3.3 Correlation analysis

In this part of the study, the correlation between NDVI and lands surface temperature is carried out to find the relationship between these variables. Table 2 shows the correlation results.

By calculating the correlation between LST and NDVI, From Table 2 it can be clearly noticed that, NDVI and LST show a high negative correlation in all years of study except 2013.

Table 2. Correlation between NDVI and LST.

Date		LST
1984	NDVI	-62%
1990	NDVI	-49%
2000	NDVI	-51%
2006	NDVI	-47%
2011	NDVI	-19%
2013	NDVI	56%

4. Discussion

The research includes spatial analysis of the standardized LST with regard to different land use types. Basic zonal statistics such as mean standardized LST and percentage share of hot and cold regions within 62 land use types were calculated. GIS was used for automated data processing through years 1984, 1990, 2000, 2006, 2011 and 2013. The values acquired from zonal statistics table are LST original raw values and should be converted from kelvin to celsius.

As shown in Table 3, among all the years highest temperature of lands surface belongs to Terminal except year 2000, which the highest degree is registered with bare soil. In 1984 the lowest temperature of land surface temperature is registered with green space while in both 1990 and 2000 the lowest degree belongs to the industrial region. In the next 3 years (2006, 2011 and 2013), min LST is allocated to Official, Residential and Utility categories, respectively.

Table 3. Result of LST in different years.

Year	Max temperature	Min temperature
1984	Terminal=44.85 ºC	Green space =20.85 ºC
1990	Terminal=36.85 ºC	Industrial=15.85 ºC
2000	Bare soil= 40.85 ºC	Industrial=19.85 ºC
2006	Terminal=42.85 ºC	Official=20.85ºC
2011	Terminal=42.85 ºC	Residential=22.85 ºC
2013	Terminal=45.85 ºC	Utility=23.85ºC

The results confirmed the most obvious dependence of the LST on different land use types and show that the land usage will influence urban temperature. According to the results obtained average temperatures is significantly higher for land uses like Bus terminal and lower for green spaces. The higher temperature in bus terminal of Tabriz is due to the fact that these areas are characterized by build up surfaces and the amount of asphalted areas. Concrete and metalic roofs in addition to the darker color of roofs and asphalt which have the low emissivity and higher heat capacity can be named as another relevant factors. Also, the heat emitting from the bus engines in terminal and lack of vegetation could affect the surface temperature. The size of land use area and surface temperatures are also relevant factors; as the size of land use increases, the temperature also tends to increase. The bus terminal covers a very vast area with 508409/1744 Km in comparison with other land uses

According to NDVI results, it can be clearly noticed that both the parameters are inversely Proportional to each other. It means that, when the temperature increase, the NDVI value decrease which points out the decrease in vegetation density in years from 1984 to 2011. However, in 2013 in can be seen that NDVI and LST show highly positive correlation.

5. Conclusion

UHI is usually observed between urban and rural land uses, and in few studies the intra-urban patterns are examined. In this study the land surface temperature of different land uses has been analyzed and several important findings are obtained. By using Landsat ETM+ and OLI and further the impact of land use change on land surface temperature is demonstrated. In other words, the change of land use is the important reason leading to increase in land surface temperature.

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