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Relationship between Land Cover Use and Urban Thermal Islands by Landsat 8: Case study of Sanandaj

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Abstract

Increasing population (including natural increasing and migration) and rapid industrial growth are the main reasons of global climate change. Today, the most significant problem in urban areas is the increase in surface temperature due to changes in natural levels. In urban areas, depending on the type of land and vegetation used, areas with different temperatures develop from other areas. In this research, to answer the question that how different types of the urban usage affect the creation of high temperature areas with the aim of understanding the temperature difference between different regions of the city and the surrounding area in order to provide a thermal island map in Sanandaj, discharge and surface temperature in Sanandaj was estimated using Landsat 8 satellite data by Jenks method in summer and autumn. For this purpose, Envi and ArcGIS software were used, and finally, changes in surface temperature were evaluated in comparison with land uses, and the user role in the creation of surface temperature was determined. The results showed that wasteland, industrial and urban facilities have the highest temperature and commercial and green space has the lowest temperature. Thus, the influence of urban utilization in the emergence of current thermal conditions in Sanandaj indicates the relationship between the type of user and surface temperature.

Keywords: Urban Thermal Island, Land Use, Landsat 8 Satellite Images, Sanandaj City, Surface Temperature

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1. Introduction

Nowadays, Urbanization has flourished, and this has led the Earth to be affected by various issues, loss in natural condition to a large extent, one of the consequences of which is the rise in temperature. With urban expansion after the 1930s, especially after World War II, local climate change appeared in urbanization (Bahreini, 1992). In the twentieth century, urbanization took place at a global scale. According to UN estimates, nearly half of the world's population lives in cities. In Western societies, it is higher than 75% (UN, 1999). The most important problem in urban areas is the increase in surface temperature due to changes occurring at natural levels, uncontrolled growth of cities, especially big cities, due to the natural urban population growth, the increase of rural migration, etc. They sought to increase the environmental degradation and the increasing number of contaminations (Wairmn yazdi, 2000). Urbanization has altered all kinds of land cover in urban areas, which has led to the formation of distinct urban weather (Rose.et al., 2009). Urban heating is one of the most well-known forms of local manipulation of the climate by mankind, so that changes in the use of land cover in urban areas can lead to an increase in urban temperatures relative to air temperatures in rural areas. Earth surface temperatures can provide useful information on the physical properties of land and climate that plays a significant role in environmental processes (Weng et al., 2004). The thermal island effect was first observed in London and other European cities in the 1930s, followed by cities such as New York and Chicago. The phenomenon is now an important environmental phenomenon, and wherever there are large cities, there is thermal island effect (Yamamoto, 2006). Urban areas are warmer than their surrounding countryside, for two reasons: First, the city's structure and morphology has the potential for absorbing and storing pure solar radiation, especially in the calm and smooth summer weather. This leads to overnight warming in the city center (business district) and the formation of a thermal island in the summer. The business center of big cities can be 6 to 8 degrees centigrade warmer than their suburbs. Second, large thermal islands are caused by the release of heat by human activities caused by processes such as fuel (especially in metropolises during winter). In addition, smoke and vapor coatings reduce the loss of heat by night-time wavelengths in urban areas, and consequently the greenhouse effect is exacerbated (Alavi panah, 2008). Due to the presence of suspended particles, the city receives less sun than the rural areas and is, however, warmer than neighboring rural areas. Because the city's environment, due to the heat generated by the use of fossil fuels, and because of the impermeable levels and high buildings, acts as a heat collector, resulting urban heat island is formed in the city. The specification of the city's thermal island increases the difference between the temperature of the city and its adjacent rural areas. The city is weathered by climate, local wind patterns, cloud and fog development, and rainfall rates, and in some cases leading to diseases such as asthma and respiratory diseases. Several important factors affect the thermal behavior of urban areas:

1. Physical properties of various components of urban areas
2. Geometric shape of the ground
3. Weather conditions

Research by the Lawrence Berkeley National Laboratory in Berkeley, California on the summer days in Los Angeles, the temperature rises to a degree Fahrenheit, increases the risk of mascara up to 3% (noak, 2000). The haze of smoke or surface ozone (in contrast to the ozone that protects the earth against ultraviolet radiation) is invisible pollutants which can permanently damage the lungs (Mhrgan, 2013).

Plant growth season in urban areas is fifteen days longer than rural areas and in addition to the effect of temperature, it produces secondary effects, such as local wind, cloud and fog, and accelerated precipitation. Likewise, building materials during the day store large quantities of thermal energy and it returns during the hours of the night. This process will delay the natural process and cool the city air; and the negative aspects that are very important are the studies that emphasized the impact of island heat on residents and urban life among the co-authors of Subrino, studying the thermal island of Madrid, assessed its role on thermal comfort throughout the day and night. Sue et al. determined the relationships between land cover and surface temperature on urban Thermal Island and its effects on population and showed that the city's thermal island was underestimated by the global model and the risk of disease has increased urban populations (Alavi panah, 2006).

The warming of the urban environment calls the steady rise of "thermal islands" steadily throughout the world and has created a difficult environmental situation for urban residents. Therefore, it is important to recognize these processes and make the appropriate decision for urban management (Nakamura, 2002). The thermal island in the cities can add a lot of heat to the city due to high thermal capacity of building materials, industries, vehicles and thermal baths, air pollution, high-rise buildings and towers create heat exchange problems (Azizi, 2014). Urban thermal islands, in addition to the above, arise from the destruction of forests and the change in the surface cover of the surface to evaporated surfaces, such as asphalt and pavement (Alavi panah, 2006).

Thermal island studies are in the field of applied geography and climate (Alijani, 1992); which this research is seeking to know. Due to the irregular structure, it increases the energy consumption and doubles the temperature in the urban environment. Among the positive effects of heat island, the use of fossil fuels for heating homes during winter season and the growth of plants is due to increased food production in these areas (Soltaninjad, 2017). The study of the first urban thermal island was carried out using air temperature measurements of mobile and fixed urban stations based on ground data. However, the use of remote sensing data to estimate surface temperature is a relatively new method that greatly reduces the estimation cost of classical temperature (Miryaqobzadeh, 2009).

Remote sensing images due to extensive coverage, timelines and the ability to obtain information in the thermal range of the electromagnetic spectrum are a good source of information for the preparation of thermal maps and the estimation of surface radiation energy. Also, these images have different uses in the global analysis of land cover coverage of urban levels. Using these images, with proper resolution, urban thermal islands can be illustrated in different continental and regional scales, and quantitative data from the characteristics of the Earth's surface are generated by heterogeneous distribution, which results in a better understanding of urban and non-urban environments and urban temperature (Shakiba et al., 2009).

In order to generate a policy to reduce the thermal island, it is important to understand the relationship between the type of land cover and the formation of urban thermal. Remote sensing data from satellites and planes can provide infrared images through which surface temperatures can be extracted and linked to land cover and land use patterns (Mhrgan, 2013). Vegetation areas are colder than other urban areas during the day, while at night the vegetation is relatively warm. A low surface temperature during the day is due to the latent heat loss due to daily evapotranspiration (Alavi panah, 2008). The use of satellite data is a good way to prepare land cover map and it's monitoring - especially in large geographic areas (Yuan et al., 2005). Today, it is known that thermal data can complement other remote sensing data (reflection data) (Alavi panah, 2008). Thermal sensors are capable of recovering the islands of the terrestrial surface by recording the thermal radiation exerted from the surface of the areas in the sensory field of view (Balling and brazell, 1988). The study of this phenomenon and its mechanism or mechanism for urban planning are very important. Over the past two decades, there is a need for land surface temperature data for environmental studies and land resource management activities has identified the centers of thermal islands and the type of pollutants as one of the important scientific issues for their adjustment and control (Miller, 2011). By carrying out this research and its results, it can be used to understand the temperature data using geographic resources and instruments (GIS) and remote sensing methods. Their analysis is to identify places and determine higher temperatures points in the city and their contributing factors, as well as the optimal location of utilities, including polluting industries and urban transport systems, etc., by taking appropriate measures (Marofnjad, 2010).

During the process of industrialization of Iran, along with all parts of the world, the industrialization process has not been abandoned and the effects of population growth and industrialization in large cities of Iran have caused a lot of thermal islands, which requires a lot of research. Therefore, this research also investigated the relationship between the use of land cover and urban thermal islands using the Landsat 8 in Sanandaj city which gives a more precise results.

Hypotheses:

- There is a relationship between the types of uses in the city (case study) formation of thermal regions,
- There is a relationship between the green space and the average temperature,
- There is a relationship between industrial use and its average temperature.

Research purposes:

- To signify the temperature difference of regions and the surrounding area in Sanandaj and to determine the critical temperature areas,
- To determine the relationship between type and temperature at the city level,
- To determine of the effect of land cover and land use type on the surface temperature of the city.

2. Materials and Methods

In this research, different data sources, including Landsat 8 satellite imagery, urban land use map and temperature data from meteorological stations were used. Also, various software were used to correct and prepare the data and implement the techniques.

2.1. Data Used

2.1.1. Landsat Satellite Image 8

Table 1. Specifications of Landsat Satellite 8 images used in research

Satellite	Pass number	Row number	Year	Month	Day	Season
Landsat 8	167	35	2017	June (6)	28	Summer
Landsat 8	167	35	2017	December (12)	5	Fall

In this study, Landsat 8 satellite imagery, 167 and 35th row, were used on June 28 (7th of July) and December 5th (December 14th) in 2017. Some of the specifications with this satellite are summarized. The satellite, originally called LDCM, is a product of NASA and the United States Geological Survey (USGS).

With the retirement of Landsat 5 in early 2013, Landsat 7 was the only satellite on the orbit of the Landsat Satellite series Landsat 8 will receive continuous data and will ensure the availability of Landsat data using two sensors, one OLI imaging sensor and another infrared thermal sensor (TIRS). The two sensors collect image information for nine bands and two bands of thermal wavelength, respectively. Landsat 8 takes about 400 images a day, which has increased significantly in Landsat 7 compared to 250 images a day. Landsat 8 has a number of special features compared to the previous Landsat sensor:

OLI and TIRS sensors improve the signal-to-noise ratio (SNR) in radiometric performance, and as a result of this 12-bit data quantification, these more bits can better describe the ground cover.

1. In Landsat, the 8 Earth Field Imaging Device (OLI) uses the Push Broom system, which makes it more sensitive, less moving parts and better ground information.

2. The existence of two new spectral bands, the Blue Coastal band and the short infrared cirrus band, it allows specialists to measure the quality of water as well as high and thin clouds.

3. By registering TIRS data with OLI data, 12-bit Landsat 8 products will be produced Geometric, radiometric and terrestrial corrections have been applied to them. The table below shows the characteristics of the spectral bands of the OLI and TIRS sensors.

Table 2. Specifications of OLI Spectral Bands (NASA site)

Resolution	Wavelength	Spectral band
meters 30	Micrometer 0.433–0.453	Band -1- Band Coastal / Aerosol
meters 30	Micrometer 0.45- 0.515	Band 2 - Blue
meters 30	Micrometer 0.525 –0.60	Band 3- green
meters 30	Micrometer 0.63 – 0.68	Band 4 - Red
meters 30	Micrometer 0.845-0.885	Band 5 - Near Infrared
meters 30	Micrometer 1.56 –1.66	Band 6 - Infrared short wavelength
meters 30	Micrometer 2.100 – 2.300	Band 7 - Infrared short wavelength
meters 30	Micrometer 0.58-0.680	Band8-Panchromatic
meters 30	Micrometer 1.360 – 1.390	Band9-Cirrus

Table 3. Specifications of TIRS Spectral Bands (NASA site)

Resolution	Wavelength	Spectral band
meters 100	10.30 – 11.30	Band 10 - Infrared wavelength band
meters 100	11.50 –12.50	Band 11 - Infrared wavelength band

2.2. Application Used

In addition to general office software, the software uses various image processing and geographic information systems including Arc GIS, Envi 5 software.

2.3. Research method

The stages of this research work, the preparation of required data, heat image and thermal image of Sanandaj city. The role of topographic factors on thermal islands and ultimately determining the contribution of each urban application to the formation of thermal islands.

2.3.1. Preparing Data

2.3.1.1. Geometric Corrections

The Landsat 8 image, L1TP level, was presented in the GEOTIFF format, in which accurate geometric corrections were made and reference ground. There is no need to correct it.

2.3.2. Provide Thermal Map of TIRS Sensor Data

To prepare the thermal map, the 30-meter Band 10 at Nadir was used to study and determine temperature differences among complex urban phenomena and effective analysis of the urban climate. The image with a good atmospheric conditions, in the middle of the warm and cold season, allows us to compare the thermal islands. Since this study emphasizes on the differences in temperature among different phenomena and the extraction of information in the homogeneous spatial range taken at an atmospheric point of view, the sensor illumination temperature can be used to obtain surface temperature. The steps of preparing the surface temperature image are shown in Figures 1 and 2.

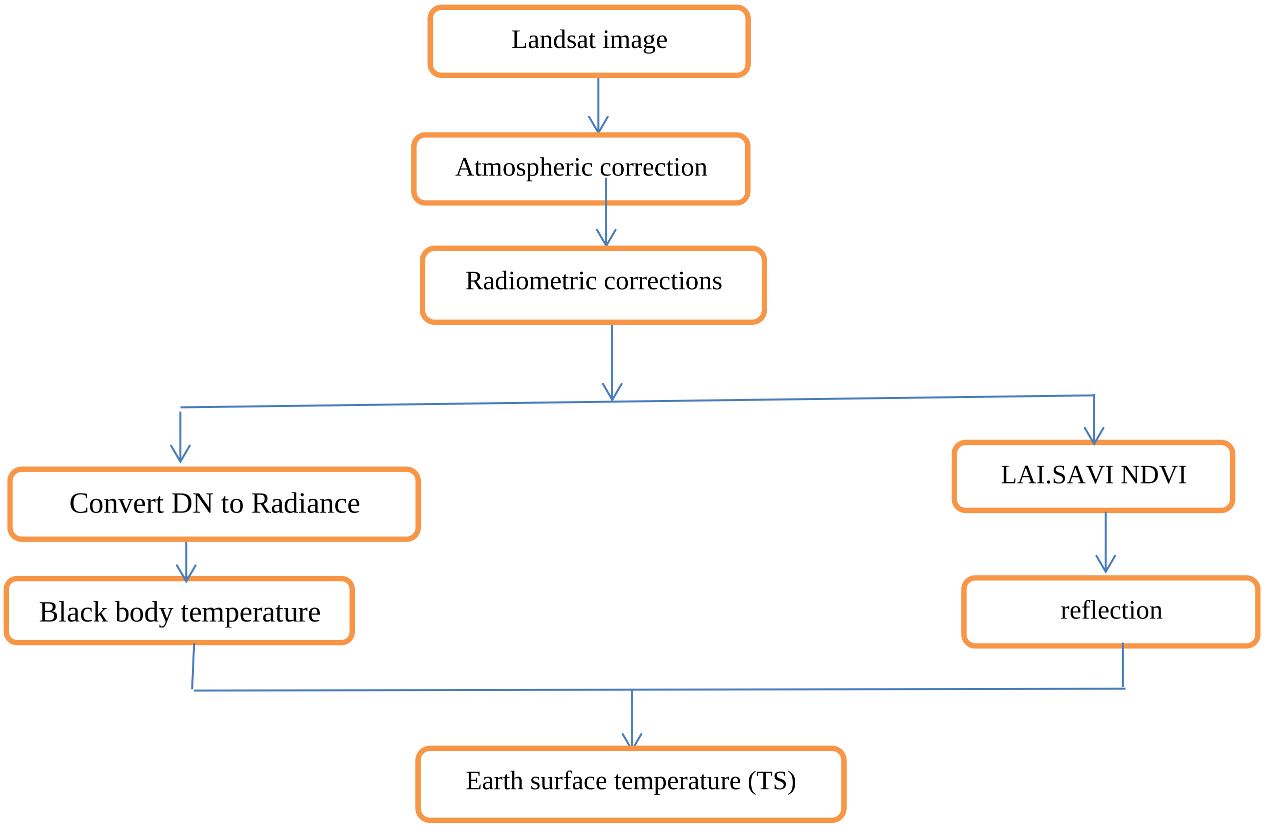

Figure 1. Land surface temperature calculation process for Sanandaj

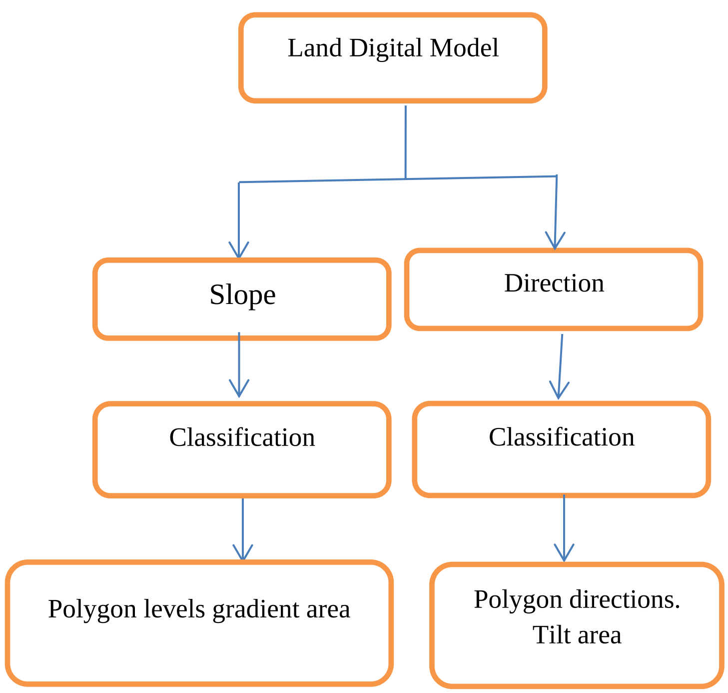

Figure 2. Steps for creating gradient and slope directions

2.3.2.1. Fluid Method for Calculating Surface Temperature

In this method, surface temperature is obtained by using corrected thermal radiations (Aleen et al., 2002). To calculate the corrected thermal radiance, there is a need to release the thermal bond. To calculate the emission in the thermal band, it is necessary to calculate the spectral radiance (λL), reflection in each band (λL) and Albudo is superficial.

Spectral Radiation (λL)

Spectral radius is the radiation emitted from the atmosphere by the detector. The radius of watts per square meter is in micrometers. Spectral radii for each band are obtained by relation (1) (Aleen et al., 2002):

$$L_{\lambda} = \text{Gain}*DN+\text{Bias} \qquad (L_{max} - L_{min})/65535 = \text{Gain} \quad (1)$$

DN = Grayscale pixels

L_{min} = Bias

Lmax and Lmin values (the maximum and minimum detectable spectral radii of any band by the sensor)

For OLI and TIRS sensors using the reference file, see Table 4.

Table 4. Highest and Lowest Detectable Radians in each band by Landsat 8

Band	Radiance - max	Radiance - min
1	755.65753	-62.40244
2	770.57178	-63.63407
3	705.58380	-58.26734
4	597.58630	-49.34887
5	362.62201	-29.94544
6	91.36265	-7.54476
7	29.72010	-2.45430
8	673.14319	-55.58838
9	149.01643	-12.30583
10	22.00180	0.10033
11	22.00180	0.10033

In this study, Landsat 8 satellite imagery, passage 167 and row 35, dated on June 28th and December 5th, 2017, were used. First, in all bands, the study area was sub-divided and stored (Figure 3 and 4).

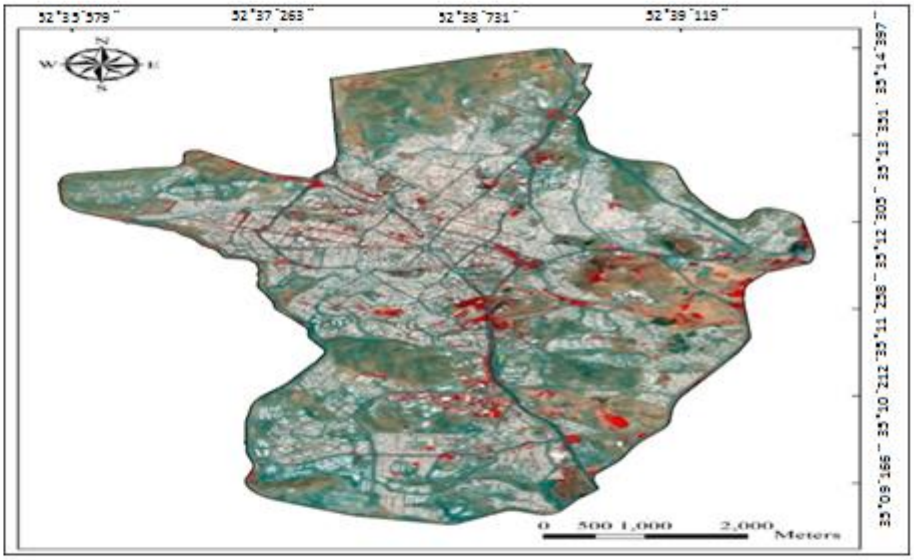

Figure 4. Landsat 8 satellite image from Sanandaj, date 5.12.2017, color combination of bands 5-4-3

2.3.2.2. Investigating the Relationship between Ground Temperature and Urban Usage

In order to investigate the role of each application in the creation of thermal islands and to increase the temperature of the earth surface, the static zoning command was used in the GIS environment. Figures 5 and 6 shows the average temperature of each runway in Sanandaj.

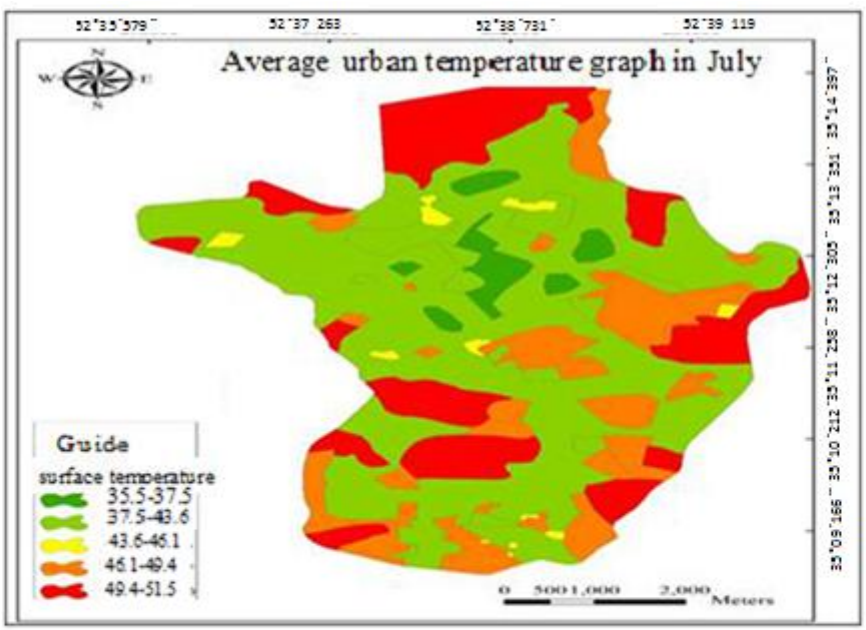

Figure 5. Sanandaj average sanitation rate map on 28.6.2017

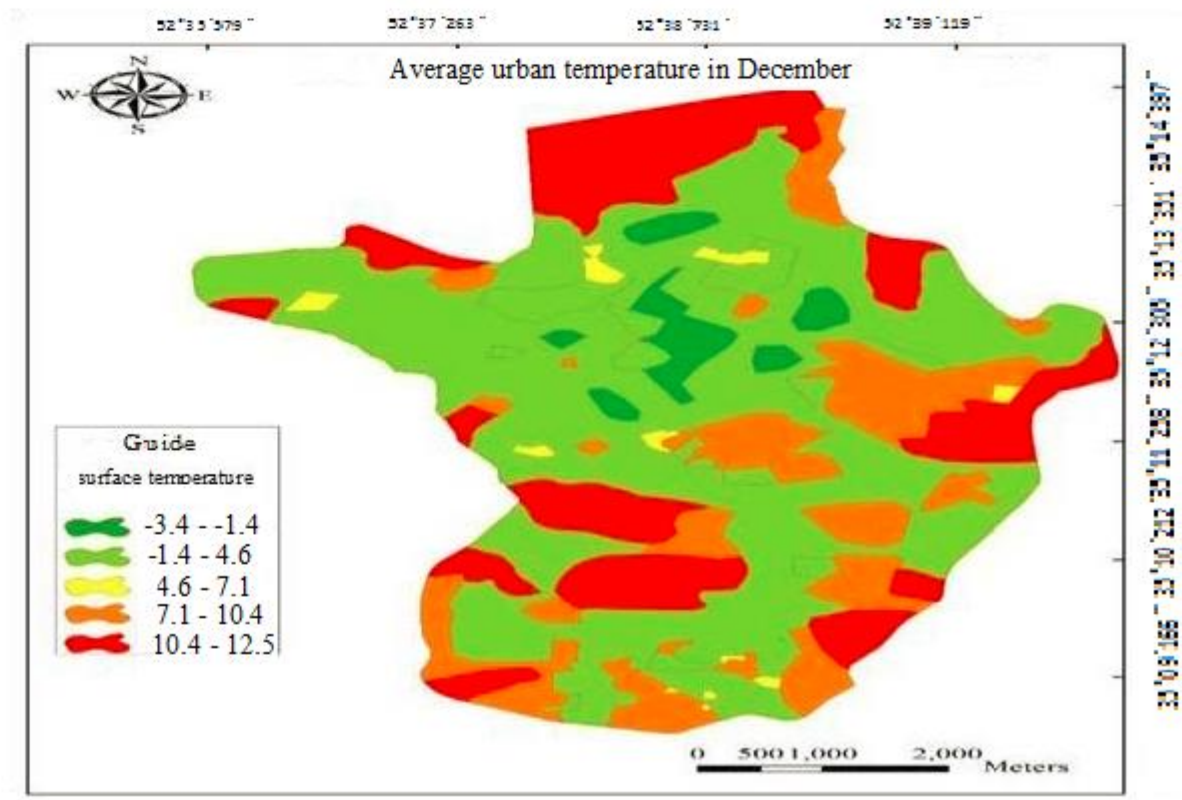

Figure 6. Sanandaj average sanitation rate map on 5.12.2017

Charts 1 and 2 Temperature-user relationship in July and December

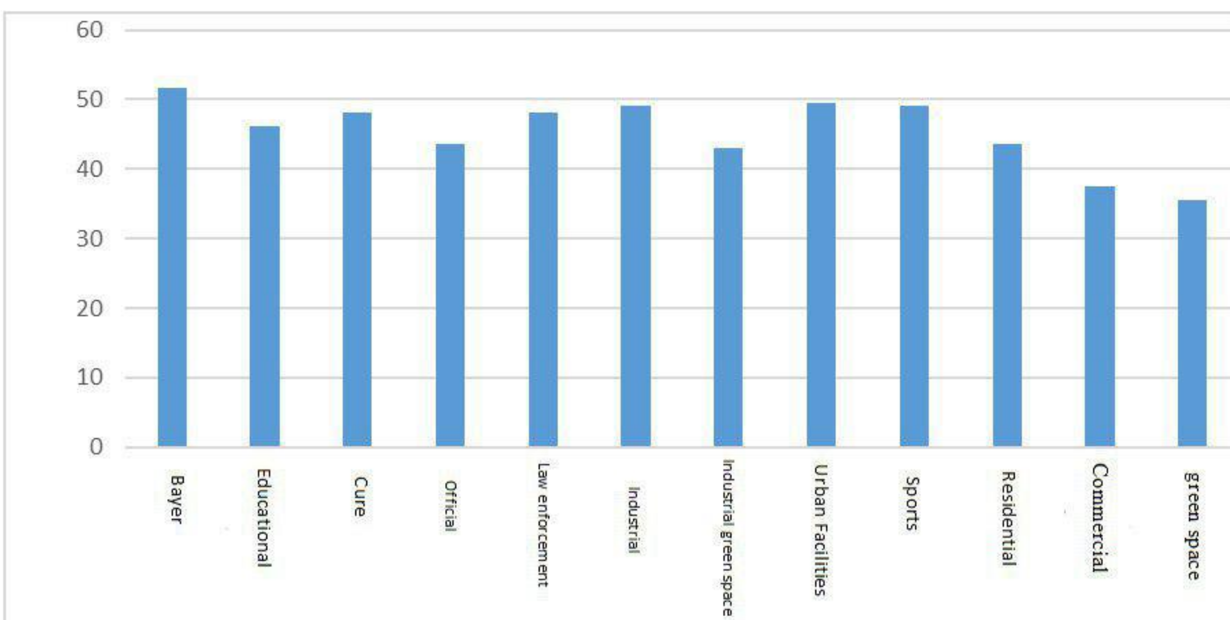

Chart 1. Sanandaj urban-temperature on 28.6.2017

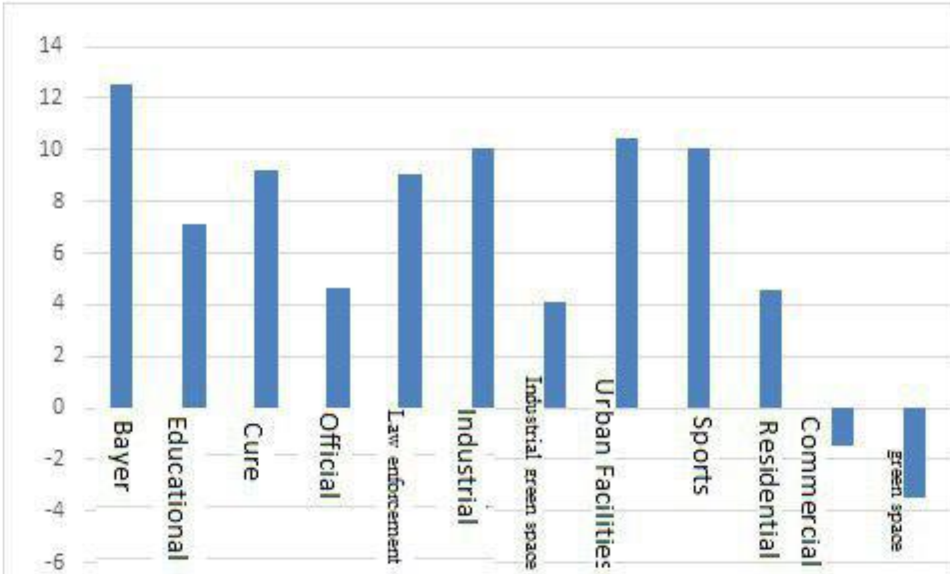

Chart 2. Sanandaj urban temperature on 5.12.2017

As it can be seen from the above charts in July, the best industrial and urban facilities had the lowest temperature, commercial use and green space. In December, Bayer (bare land), industrial and urban facilities had the highest temperatures and commercial use and green space.

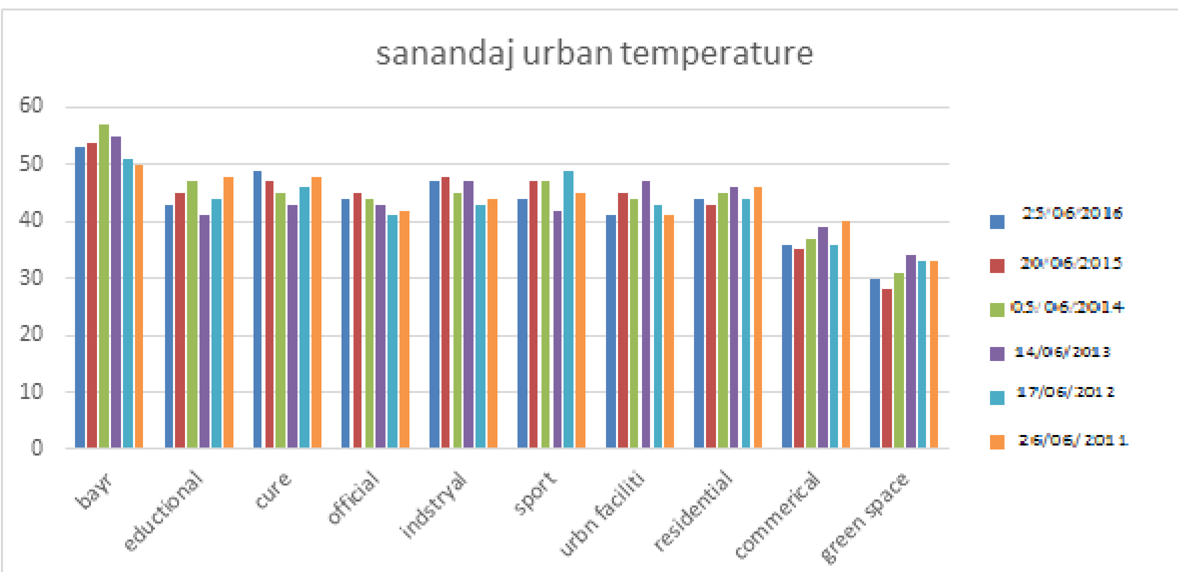

Chart 3. Sanandaj urban-temperature

Chart 3 shows that the temperature of Sanandaj city is different for different uses, and this over a period of 6 years, allows us to compare the user temperature, which indicates the temperature in the same time period (July).

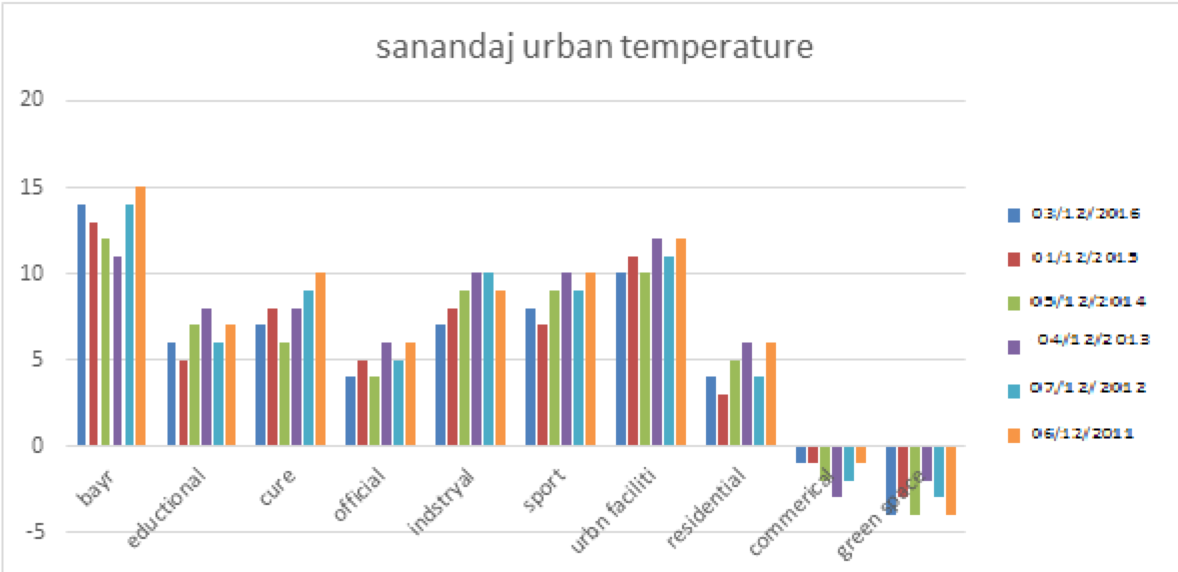

Chart 4. Sanandaj urban temperature

Chart 4 shows that the temperature of Sanandaj city is different for different uses, and this over a period of 6 years, allows us to compare the user temperature, which indicates the temperature in a similar time period (December). As you can see from the above, in July, the best industrial and urban facilities had the lowest temperature, commercial use and green space. In December, Bayer (bare land), industrial and urban facilities had the highest temperature, commercial use and green space.

3. Discussion and Conclusion

There is a relationship between the type of applications in the city (case study) and the formation of thermal regions. Feyzizadeh and Plazchak (2016), in their paper, calculated the surface temperature for the Maragheh city by the SEBAL method. The results show that there is a difference of 6% measured surface temperature (Faizizadeh et al., 2016).

Owen et al. (1998) at the University of Pennsylvania in a research entitled "Remote Sensing Surveillance Indicator Parameters in describing the quantitative climate impacts of urbanization" addressed the impacts of urban utilization on urban temperature determination and evaluated them (Owen, et al.,1998).

Carlson et al. (2000) investigated the effects of land use and vegetation changes in the Chester area of the United States. In his research, he used the TM and AVHRR imaging for NDVI and ISA extraction, and concluded that the magnitude of the ISA between two times (1996-1996) increased from 1.29 to 0.19 (Carlson et al., 2000). According to the urban utilization layer, Figures 1 and 2, it can be seen that there is a relation between urban type and formation of thermal regions which confirms the hypothesis. There is a relation between the hypothesis between the green space in a region and its average temperature.

Wang et al. (2003) proposed a successful way of determining the relationship between LST and land use patterns and land cover using remote sensing data and land echelon ecological methods. In this study, using the ETM + image of Indiana Police, images of green vegetation, soil, regions, or Albdeau highlands and landscapes with low albedo were obtained using spectral separation model.

Then impenetrable surfaces were extracted from high-resolution images and images with low albedra. Subsequently, a hybrid classification was used to develop the classification of fractional images into seven user levels and land cover. In fact, the Landscape pattern fragmentation images were obtained and the correlation of the subpixel image extracted with the Landscape fraction components was investigated. The results indicated that the extracted fragment images significantly reflect the morphology of the city, which showed a logical relationship with the city's bio-physical characteristics. The temperature was positively correlated with non-penetrating surfaces and negative relation with green vegetation (Wenget al., 2004).

Green space in the city depends on the location of the area so that there is enough green space in one of the factors not forming thermal islands in the densely populated urban areas. Conversely, there is a high temperature and the formation of thermal islands in the Bayer areas due to the lack of green space. So, one can conclude that there is a relation between the green space and the average temperature of that relationship is reversed, that is, lesser the green space lower is the temperature, so this hypothesis is also confirmed.

In the hypothesis, there is a relationship between the industrial user in one region and its average temperature.

Great islands are caused by the release of heat by human activities caused by processes such as fuel, especially in winter. In addition, the smoke and vapor coating caused by industrial activities reduce the loss of heat by night-time wavelengths in urban areas and, as a result, the greenhouse effect intensifies. The relationship between industrial user and temperature is clear and this relationship is as shown in Figures 1 and 2. It is straightforward that more the industrial centers, the higher the temperature in those areas which confirms the hypothesis.

-Earth surface temperature is one of the key factors, because it is equivalent to the air temperature of the lower layers of the urban atmosphere, which is the center of energy balance. It affects the lives and comfort of urban residents. Thermal islands are characterized by different atmospheric layers of the city, and are normally divided into two categories: the atmospheric thermal islands (Thermal Layer), and the thermal islands of the earth's surface layer.

-Thermal sensors are able to recover terrestrial thermal islands by recording the thermal radiation exerted from the surface areas in the sensor field. In general, LST is a large area of thermal islands. These islands are more visible in July.

At Sanandaj airport, especially the main passenger terminal of Saqez, low vegetation, existence of low asphalt surfaces with high thermal conductivity and the borderless areas of airports that do not perform moderating evaporation in the summer due to the lack of moisture, the formation of thermal islands in these areas. There is also a lot of cars and the presence of impermeable surfaces due to the increase in the temperature of passenger terminals in the city of Sanandaj.

-In streets and highways with high traffic on Sixth Bahman Avenue, Palestine Street, Iqbal Square, Sanandaj Highway - Hamadan and Sanandaj Highway - Kermanshah, the thermal islands of these areas, in addition to the mentioned factors, increase in the temperature of impermeable surfaces and increases the tangible heat. Heat and pollution are also due to fuel consumption. In the summer, one of the main causes of heat pollution is vehicle-related pollution. Cars produce nitrogen gas and carbon monoxide, which increases the temperature after absorbing long wavelengths and reflecting them into space.

-Residential areas of the city (such as Golshan, Farah, Farah, Sirous and Abbasabad) despite impermeable surfaces, the calculated temperature is related to the early hours of the morning, Residential buildings (roofs and bricks) are warmer than the industrial and industrial zones. That's why thermal islands are not formed in these areas.

-According to these results, thermal islands are not always located in city centers, but in the marginal areas of cities where the distribution of industries in these places is higher because of the presence of asphalt, concrete and pollution, as well as in the Bayer (bare land) areas in the city and the outskirts due to the lack of use evapotranspiration cooling mechanisms has high heat absorption capacities and low conductive capacity.

-According to the comparison of the results of terrain thermal images in July and land cover, it is evident that their spatial distribution has the same pattern, so that for the layers of application the highest is in the areas of waste, industrial and urban facilities, average temperatures to residential and administrative areas, the lowest temperatures to the regions is the commercial and green areas.

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