The Link between Urbanization and Climatic Factors: A Concept on Formation of Urban Heat Island

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Abstract: - Increasing the number of population, pollutions, urban expansion and many other kinds of urbanization factors in metropolitan areas are affected climatic factors and vice versa. In fact, there is a correlation between these two factors in general. This paper put forward the conceptual model and two hypotheses. In order to test the model, UHI mapping has been carried out in Tehran as a case study. The investigation has been done at macro-level to get surface temperature. The methodology employed is to use satellite image with a thermal band (obtained on 18 July 2000). To map out the UHI, mapping of LST and NDVI were necessary and then overlaid them and extracted maximum temperature value for both urban and rural areas. The results show that the maximum urban and rural temperature values are 39°C and 27°C respectively. Therefore, daytime Tehran surface UHI shows 12ºC of difference between urban and rural areas which is quite strong. Analyzing the data specified that the urbanization factors have direct impact on increasing the UHI intensity in Tehran metropolitan area.

Key-Words: - Climatic Factors, Environmental Challenge, Tehran, Urban, Urban Heat Island, Urbanization Factors

1 Introduction

Since urban heat island is due to two factors, urbanization and climatic factors, many features of the physical structure of the city can affect the urban climate and with negative impacts lead to increase UHI intensity. In addition, it is not always a one way influence from urbanization toward climate. Increasing of temperature and sunlight, decreasing wind speed, humidity and precipitation can be major factors on formation of UHI. As a matter of fact, existing the interaction between urbanization and climatic factors may influence greatly on formation of UHI. In other words, the percentage of UHI formation is high when great interaction exists.

Therefore, according to the above concept, it becomes increasingly important to investigate effective factors on formation of UHI and the correlation between these factors in order to recognize the formation way of UHI [1].

Thus, this paper explores a conceptual model in order to show the correlation between these two factors and how they can influence on formation of UHI on different layers of city. However, this paper only focuses on urbanization factors and surface UHI.

2 Recognition of all dimension of urban heat island

The majority of cities are sources of heat, pollution and the thermal structure of the atmosphere above them is affected by the so-called “heat island” effect. A heat island is best visualized as a dome of stagnant warm air over the heavily built-up areas of cities [2]. The heat that is absorbed during the day by the buildings, roads and other constructions in an urban area is re-emitted after sunset, creating high temperature differences between urban and rural areas [3]. The exact form and size of this phenomenon varies in time and space as a result of meteorological, locational and urban characteristics [4]. Therefore, urban heat island morphology is strongly controlled by the unique character of each city. As it can be seen in Fig. 1, Oke [4] stated that a larger city with a cloudless sky and light winds just after sunset, the boundary between the rural and the urban areas exhibits a steep temperature gradient to the urban heat island, and then the rest of the urban area appears as a “plateau” warm air with a steady but weaker horizontal gradient of increasing temperature towards the city center.

The heat island phenomenon may occur during the day or during the night. Givoni [5] mentioned that the largest elevations of the urban temperatures occur during clear and still-air nights. During these times temperature elevations of about 3-5°C are common, but elevations of about 8-10°C were also observed. Today, the majority of cities are around 2°C warmer than rural areas and commercial and height density of residential areas are hotter between 5 and 7°C [6]. There are some main parameters, city size and population, weather conditions such as cloud cover, wind speed, humidity, urban canyon characteristics, etc., which influence the temperature increase in cities and play significant role on it.

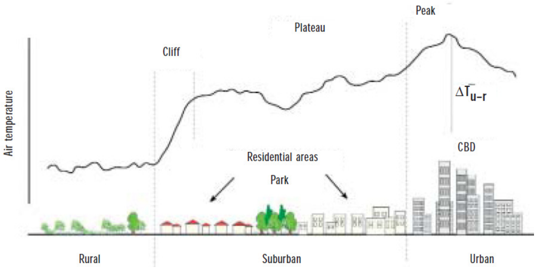

Fig. 1 theoretical urban temperature cross-section [4]

IPCC [7] has compiled data from various cities so as to be able to assess the impact of the heat island. The data show that the effect is quite strong in large cities. The temperature increase due to the heat island varies between 1.1 K and 6.5 K (Table I).

3 Conceptual Model: Correlation between Urbanization and Urban Climatic Factors on Formation of UHI

It is clear that climate has major impact on urbanization. Temperature, precipitation, humidity, wind, sunlight and other climatic parameters can greatly influence the design of the city in terms of its general structure, orientation, building forms, materials and the like. Instance, in hot arid areas, structure of the city is densely and compact in order to avoid penetration of sunlight.

Table I UHI effects in some cities [7]

City	Temperature Increased (K)
30 US Cities	1.1
New York	2.9
Moscow	3-3.5
Tokyo	3.0
Shanghai	6.5

Wong and Chen [8] stated that climate has impacts on buildings in terms of their thermal and visual performances, indoor air quality and building integrity. For example, a properly oriented building will receive loss solar heat gain and result in better thermal performance. In addition climate can influence the pattern of energy consumption.

It is not always a one way influence from climate toward urbanization. Urbanization, especially in higher density of built-up areas, has more influence climate. Buildings in cities influence the climate in five major ways [9]:

1) By replacing grass, soil and trees with asphalt, concrete and glass;
2) By replacing the rounded, soft shapes of trees and bushes with blocky, angular buildings and towers;
3) By releasing artificial heat from buildings, air conditioners, industry and automobiles;
4) By efficiently disposing of precipitation in drains, sewers and gutters, preventing surface infiltration; and
5) By emitting contaminants from a wide range of sources, which, with resultant chemical reactions, can create an unpleasant urban atmosphere.

Urban areas are the sources of anthropogenic carbon dioxide emissions from the burning of fossil fuels for heating and cooling; from industrial processes; transportation of people and goods, and the like [10], [11], [12], [13], [14], [15]. Increased in pollutant sources both stationary (industrial) and non-stationary (vehicles) result in worsening atmospheric conditions [16]. The urban environment affects many climatological parameters. Global solar radiation is seriously reduced because of increased scattering and absorption [12]. Many cities in the tropics experience weak winds and limited circulation of air which helps the accumulation of pollutants [16]. The wind speed in the canopy layer is seriously decreased compared to the undisturbed wind speed and its direction may be altered. This is mainly due to the specific roughness of a city, to channeling effects through canyons and

Table II comparison of climate variables between urban and rural areas [20]

Meterological Parameter		**Compared with Rural Areas**
Radiation	Solar radiation	Less
	Ultraviolet radiation (winter)	Less
	Ultraviolet radiation (summer)	Less
	Sunshine duration	Less
Air Temperature	Annual mean	Higher
	Radiation days	Higher
	Minimum temperature	Higher
	Maximum temperature	Higher
Humidity	Relative	Less
	Absolute	No change
Fog		Less
Cloudiness		More
Precipitation	Annual mean	More
	Snow	Less
Wind	Mean wind-speed	Less
	Calms	More
	Gusts*	Less

also to the heat island effects [12]. In addition, higher temperatures increase the production of secondary, photochemical pollutants and the high humidity contributes to a hazy atmosphere.

In parallel, the urban environment affects precipitation and cloud cover [17]. The exact effect of urbanization depends on the relative place of a specific city with respect to the general atmospheric circulation [12]. For example, urbanization causes a proportional increase in precipitation in cities like London, which, because of its geographic location, is more often in a perturbation zone, than in cities like Paris [3].

The city affects both physical and chemical processes in the atmospheric boundary layer (the lowest 1000 m of the atmosphere) [18], [19] including:

1) Flow obstacles;
2) The area of an irregular elevated aerodynamic surface roughness;
3) Heat islands; and
4) Sources of emissions, such as sulfate aerosols that affect cloud formation and albedo.

Table II shows the modification of meteorological parameters in urban areas. One of the best known phenomena of the urban climate is the urban heat island. The term urban heat island denotes the increased temperature of a city compared with the temperature of the surrounding rural area. Therefore, the temperature difference increases with an increase in the number of inhabitants and the building density [1]. According to Table II, in an urban area, an increase in the number of inhabitants and the building density is caused higher temperature rather than rural areas, as well as lower humidity due to low albedo and non-reflective materials, lower wind speed due to high density, which they can provide different kinds of urban heat islands over the city.

Table II comparison of climate variables between urban and rural areas [20]

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Humidity	Relative	Less
	Absolute	No change
Fog		Less
Cloudiness		More
Precipitation	Annual mean	More
	Snow	Less
Wind	Mean wind-speed	Less
	Calms	More
	Gusts*	Less
Contaminants	Particles	More
	Gases	More

Many kinds of urban heat islands can be identified depending on what kind of temperature is examined. Depending on settlement structures, not only one urban heat island develops but an urban heat archipelago [20]. The various urban heat islands display different characteristics and are controlled by different assemblages of energy exchange processes. According to the Oke [4], there are different types of UHI which can be classified as below:

1) Air UHI, which include urban canopy layer heat island (UHIUCL) found in the air layer beneath roof-level and urban boundary layer heat island (UHIUBL) found in the air layer above roof-level. These are closely coupled but have different magnitudes and are generated by different processes;
2) Surface UHI, this kind of UHI can be distinguished based on the temperatures of urban surfaces; and
3) Sub-surface, found in the ground beneath the surface.

Fig. 2 illustrates the interaction between urbanization and climatic factors as a conceptual model which is caused the formation of UHI in different layers.

Based on the model, two fundamental hypotheses can be

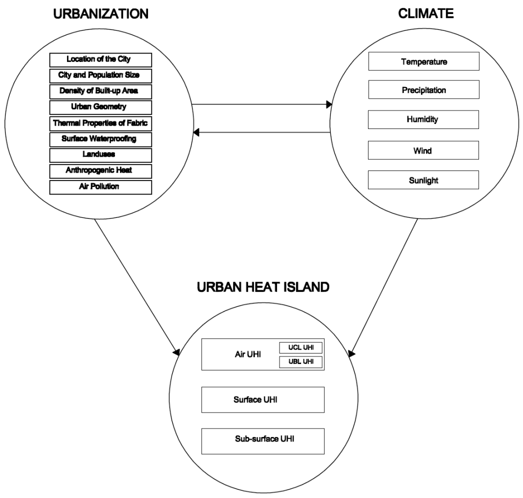


Fig. 2 conceptual model: interaction between urbanization and climate factors

generated:

Hypothesis (1):

UF↑ →UC↑→UHI↑ and CF↑ →CU↑→UHI↑

Hypothesis (2):

UF↓→UC↓→UHI↓ and CF↓→CU↓→UHI↓

Where

UF = the amount of urbanization factors (↑ increase and ↓ decrease)

UC = the effect of urbanization factors on climate (↑ increase and ↓ decrease)

CF = the amount of climatic factors (↑ increase and ↓ decrease)

CU = the effect of climatic factors on urbanization (↑ increase and ↓ decrease)

UHI = urban heat island (↑ increase and ↓ decrease)

These two hypotheses basically show the direct correlation between urbanization and climatic factors and also their direct impacts on UHI intensity. The formation of UHI is not only related to the increasing amount of urbanization factors and their impacts on urban climate, but also to the increasing amount of climatic factors and their impacts on urbanization. By increasing the amount of urbanization factors such as density of built-up area, the impacts of them on climate rise dramatically and then caused higher UHI intensity and vice versa. Moreover, while the amount of climatic factors rise such as air temperature, the effect of climatic factors on urbanization increase and caused higher percentage of UHI formation and vice versa. Therefore, imbalanced conditions may occur due to the continuous interaction between these two factors. Under such circumstances, a balanced urban environment can be created. In other words, a balance in different aspects of these interactions is made.

Therefore, in order to test these hypotheses, UHI mapping in Tehran as a case study is necessary which will be discussed in next part.

4 Methodology of research

In order to test the model, UHI mapping has been carried out in Tehran. This paper put the model and its two hypotheses in the context of Tehran for following reason:

- Tehran is a big city, surrounded with mountains in north and east and desert in south. High density of built-up area and higher population in Tehran provided an urban area with low albedo and non-reflective materials, higher production of anthropogenic heat due to the transportation, cooling and heating system and cooking and last but not least is air pollution which Tehran is famous in this regard (urbanization factors);
- Tehran is located in the hot and dry climate, has higher air temperature in summer and lower temperature in winter. Tehran also faces with the lack of wind speed challenge (climatic factors); and
- Tehran has experienced rapid change of land use since it became capital 200 years ago which is caused some environmental problems like UHI (interaction between urbanization and climatic factors).

The investigation has been carried out at macro-level in order to get surface temperature. The methodology employed is to use satellite image. Satellite image with a thermal band was processed to obtain an instantaneous impression of the UHI. In order to map out the UHI, mapping of land surface temperature (LST) and normalized difference vegetation index (NDVI) were necessary. It aimed to overlay two images (NDVI and LST images) and extract maximum temperature value for both urban and rural area.

A Landsat ETM7+ satellite image obtained on 18 July 2000 was selected (Fig.3). The image was radiometrically calibrated

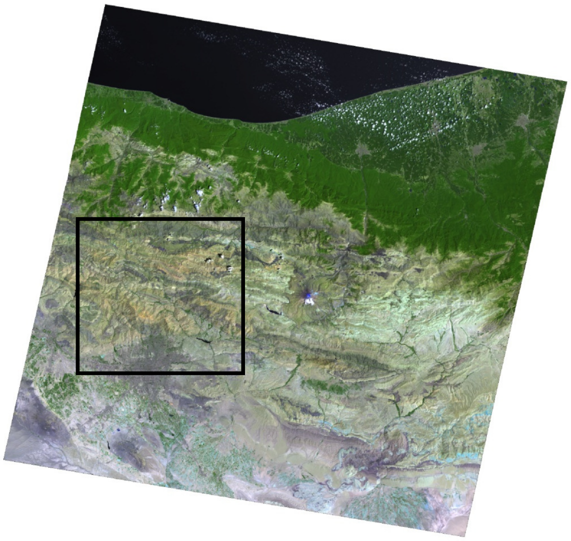


Fig. 3 Landsat-7 ETM+ image of Tehran acquired on 18 July 2000 (band combination RGB 7 5 3

and geometrically corrected to obtain the detected radiance data. The detected radiance in the thermal band was converted to equivalent surface temperatures using Planck's blackbody formula. The land cover was classified into several classes, such as vegetation, building and the like, using the visible, NIR and SWIR bands. Instead of ambient temperature, the relative surface temperature can be seen from the satellite image.

5 Tehran urban heat island measurement

1. Mapping of Land Surface Temperature (LST) Calibration for Thermal Band (Band 6) ETM7+

Spatial Modeler in ERDAS Imagine (remote sensing software) was used for converting DN to radiance according to equation (1):

$L\lambda$= (Lmax-Lmin)/(Qcalmax-Qcalmin)(Qcal) + Lmin (eq1)

Where,

$L\lambda$= Spectral radiance [W/(m^2.sr.µm)]
Lmin= Minimum spectral radiance
Lmax=Maximum spectral radiance
Qcalmax= Maximum Grey level
Qcalmin=Minimum Grey Level
Qcal= Band 62
Image date= 18 July 2000
Lmin=3.2; Lmax=12.65; Qcalmax=255; Qcalmin=1
Check in header: p164r035_7x20000718.met

So, $L\lambda$ = (12.65-3.2) / (255-1) ($n1_p164r035_7k20000718_z39_nn62) + 3.2 = dntorad_output.img

Convert Radiance to Temperature

For converting radiance to temperature equation (2) was used:

T=K2/ (ln (K1/ $L\lambda$ +1)) (eq2)

Where,

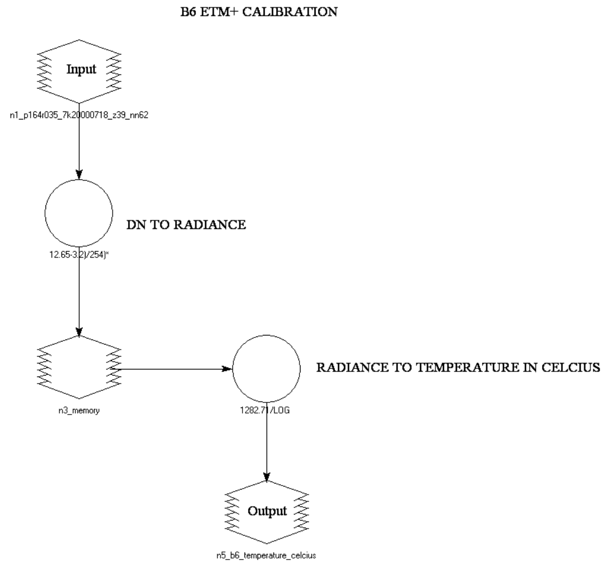
T= temperature in Kelvin
K2= constant 2 in Kelvin
K1=constant 1[W/(m^2.sr.µm)]
$L\lambda$= Spectral radiance
So, K1= 666.09 W/(m^2.sr.µm); K2=1282.71°K

Convert Temperature from Kelvin to Celsius

For converting temperature from Kelvin to Celsius equation (3) was used (Fig. 5):

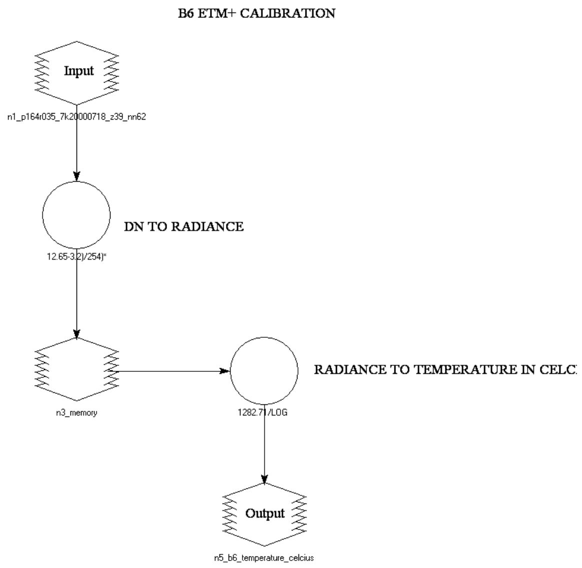
T= temperature in Kelvin -273.15 (eq3)

T= (1282.71/LOG ((666.09/$n1_dntorad_output) +1)) - 273.15
= B6_temperature_celcius



REFERENCE : Landsat-7 Science Data User Handbook (2006)

Fig. 4 the process of LST mapping (Input and Output)



REFERENCE : Landsat-7 Science Data User Handbook (2006)

Fig. 4 the process of LST mapping (Input and Output)

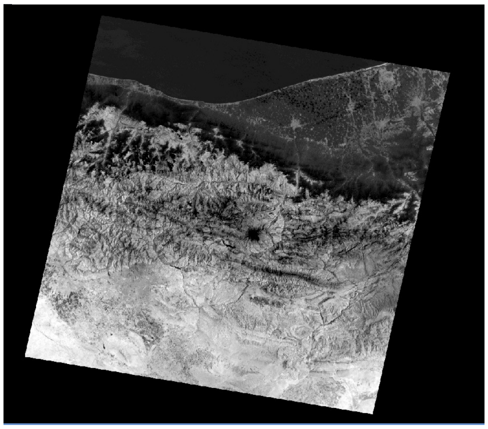


Fig. 5 output: B6_temperature_celcius.img

Mapping of Normalized Difference Vegetation Index (NDVI)

A. *Normalized Difference Vegetative Index (NDVI)*

A vegetative index is a value that is calculated (or derived) from sets of remotely-sensed data that is used to quantify the vegetative cover on the Earth's surface. Though many vegetative indices exist, the most widely used index is the Normalized Difference Vegetative Index (NDVI). The NDVI, like most other vegetative indices, is calculated as a ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum. These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrast between vegetation and soil is at a maximum.

The NDVI is a type of product known as a transformation, which is created by transforming raw image data into an entirely new image using mathematical formulas (or algorithms) to calculate the color value of each pixel. This type of product is especially useful in multi-spectral remote sensing since transformations can be created that highlight relationships and differences in spectral intensity across multiple bands of the electromagnetic spectrum.

B. *Producing an NDVI Product*

The NDVI transformation is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands using the following formula:

NDVI = (NIR - red) / (NIR + red)

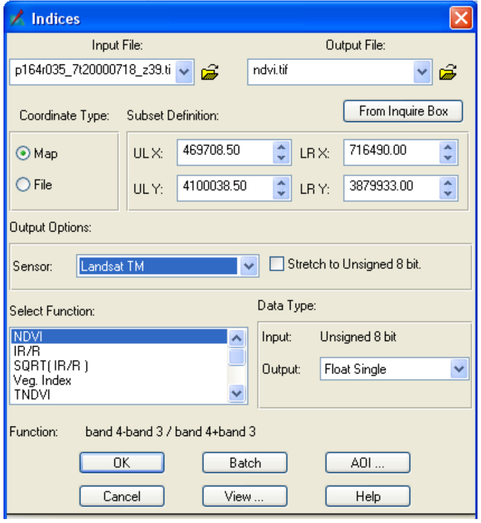
The resulting index value is sensitive to the presence of vegetation on the Earth's land surface and can be used to address issues of vegetation type, amount, and condition. Bright color mean high NDVI values and dark color mean low NDVI values.

The Thematic Mapper (TM and Enhanced Thematic Mapper Plus (ETM+) bands 3 and 4) provide R and NIR measurements and therefore can be used to generate NDVI data sets with the following formula:

(ETM+) NDVI = (Band 4 - Band 3) / (Band 4 + Band 3)

C. *Calculate NDVI: Using ERDAS Imagine*

For calculating NDVI under the ERDAS Imagine main menu is necessary to first click *"Interpreter"*, second click *"Spectral Enhancement"* and, then chose *"Indices"*. In *"Indices"* page select Function as NDVI (Fig. 6).



Input File: p164r035_7t20000718_z39.ti
Output File: ndvi.tif
Coordinate Type: ● Map ○ File
Subset Definition:
UL X: 469708.50
LR X: 716490.00
UL Y: 4100038.50
LR Y: 3879933.00
Output Options:
Sensor: Landsat TM
☐ Stretch to Unsigned 8 bit.
Select Function: NDVI
Data Type:
Input: Unsigned 8 bit
Output: Float Single
Function: band 4-band 3 / band 4+band 3

Fig. 6 indices page in ERDAS Imagine for calculating NDVI results

1. Land Surface Temperature

D. Reclassify Temperature Classes

By classifying temperature classes, maximum and minimum values were obtained as follows:

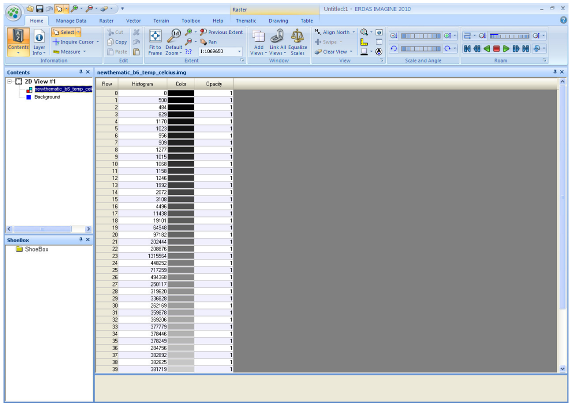
Minimum value = 1ºC

Maximum value = 48ºC

Zero value pixels are unclassified outside of the image scene. But, some areas in the image also have zero value pixels. There are some errors for temperature pixels value as the image is influences by clouds, shadows and haze.

E. Histogram Image Analysis

This analysis sorted histogram column from largest to smallest. The condition was that Histogram with value less than 10000 must not select (may cause by errors). So, temperature with 17ºC above is selected (Fig. 7).



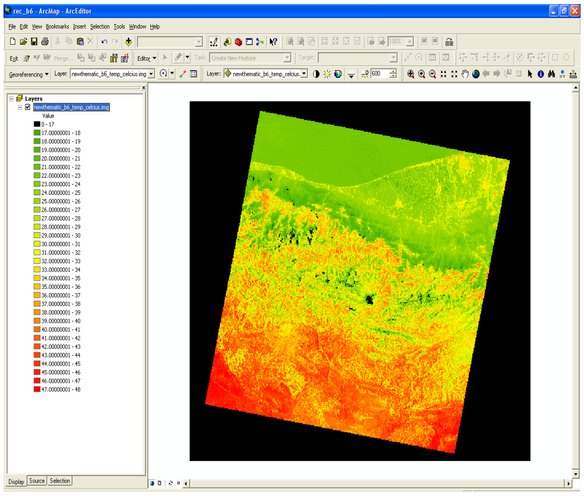
newthematic_b6_temp_celcius.img

Row	Histogram	Color	Opacity
0	0	■	1
1	500	■	1
2	484	■	1
3	829	■	1
4	1170	■	1
5	1023	■	1
6	956	■	1
7	909	■	1
8	1277	■	1
9	1015	■	1
10	1068	■	1
11	1158	■	1
12	1246	■	1
13	1992	■	1
14	2072	■	1
15	3108	■	1
16	4496	■	1
17	11438	■	1
18	19101	■	1
19	64948	■	1
20	97182	■	1
21	202444	■	1
22	208876	■	1
23	1315564	■	1
24	448252	■	1
25	717259	■	1
26	494368	■	1
27	250117	■	1
28	319620	■	1
29	336828	■	1
30	262169	■	1
31	359878	■	1
32	369206	■	1
33	377779	■	1
34	378446	■	1
35	378249	■	1
36	284756	■	1
37	382892	■	1
38	382625	■	1
39	381719	■	1

Fig. 7 Histogram image analysis

F. Using ArcGIS to Change from Gray Level Color to Class

Manual Classified is to classify to 32 classes (maximum) (Fig. 8). Color indicator is from green to red: cold to hot.



Value
0 - 17
17.00000001 - 18
18.00000001 - 19
19.00000001 - 20
20.00000001 - 21
21.00000001 - 22
22.00000001 - 23
23.00000001 - 24
24.00000001 - 25
25.00000001 - 26
26.00000001 - 27
27.00000001 - 28
28.00000001 - 29
29.00000001 - 30
30.00000001 - 31
31.00000001 - 32
32.00000001 - 33
33.00000001 - 34
34.00000001 - 35
35.00000001 - 36
36.00000001 - 37
37.00000001 - 38
38.00000001 - 39
39.00000001 - 40
40.00000001 - 41
41.00000001 - 42
42.00000001 - 43
43.00000001 - 44
44.00000001 - 45
45.00000001 - 46
46.00000001 - 47
47.00000001 - 48

Fig. 8 classification of 32 classes

2. Normalized Difference Vegetation Index

A. Land Cover Classification

The land covers types (Fig. 9) derive from NDVI classification base on NDVI value as shown in Table III.

Table III NDVI classification base on NDVI value

NDVI value	Vegetation density	Land cover type
-0.4 - -0.7	Non-Vegetation	Water
-0.0 - -0.4	Non-Vegetation	Urban area, desert & mountain area & cloud
0.0 - 0.1	Very Poor	Vegetation
0.0 - 0.2	Poor	
0.2 - 0.3	Moderate	
0.3 - 0.5	High	
0.5 - 0.7	Very High	

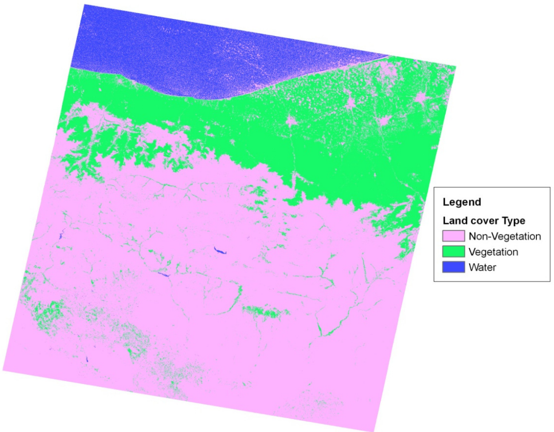


Fig. 9 land covers types

3. Tehran Urban Heat Island

The amount of heat production in urban area exceeds the amount of heat in surrounding area.

UHI = Max. (Urban Surface Temperature – Rural Surface Temperature)

By overlaying 2 images (NDVI and LST images), maximum temperature value for both urban and rural areas has been extracted. Rural has been considered as area with vegetation covers (Fig. 10).

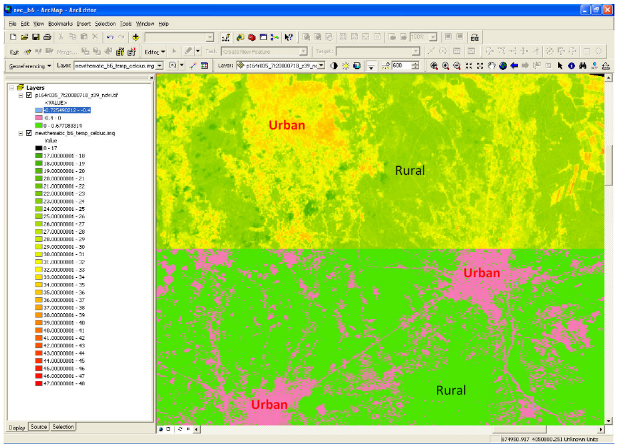


Fig. 10 overly NDVI and LST images

According to Fig. 10 maximum urban and rural temperatures are:
Urban max = 39 ºC
Rural max = 27ºC
UHI = (39-27) ºC = 12ºC
Therefore, daytime Tehran surface UHI shows 12ºC of differences between urban and rural areas as shown in Fig. 11 and Fig. 12.

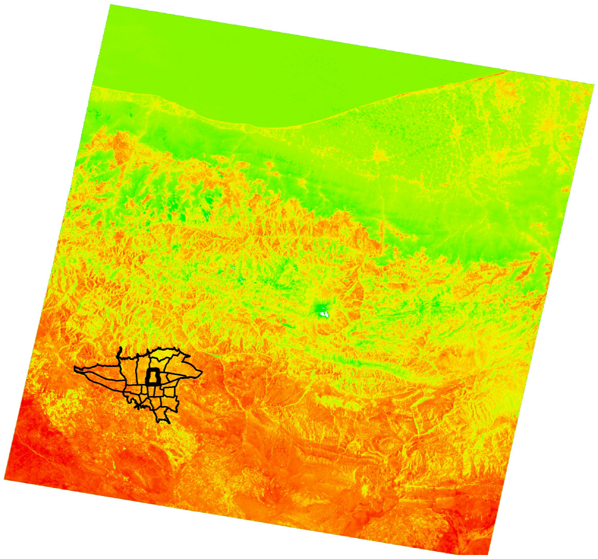


Fig. 11 Tehran surface UHI

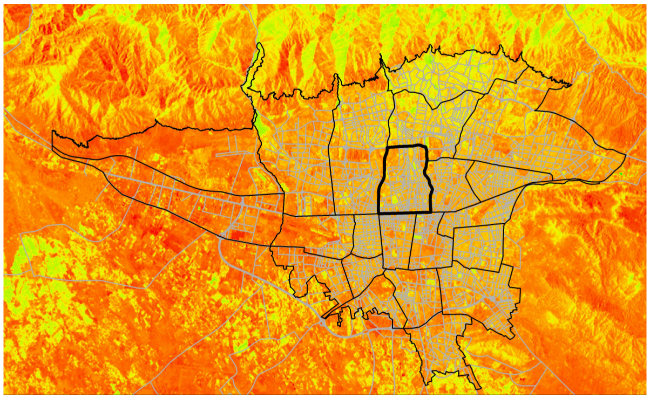


Fig. 12 Tehran surface UHI

6 Analyze and Discussion

The warm region which is represented by red and yellow color is mostly located in the central part of Tehran where the commercial areas are located and there are the higher concentration of activities and density of built-up area and the western part of Tehran where industrial areas and airport are located. On the other hand, rural areas are relatively cool with green color in the northern part of Tehran. This is due to the north mountains, some greenery and water flowed from the mountains as well as less impact from the densely placed urban developments.

As discussed previously, the elevation of about 8-10°C temperature differences between urban and rural areas is the indicator of higher UHI intensity. In this way, in Tehran the existing 12°C temperature differences between urban and rural areas, which even 2°C hotter than it has been mentioned, make a great concern about Tehran UHI. Therefore the data show that the effect of UHI is quite strong in Tehran metropolitan area which is due to the acceleration of urbanization (Fig.11).

Givoni [5] states that the differences between the urban and the rural temperatures are affected by two types of factors: (1) they are correlated with meteorological factors such as the cloud cover, humidity, and wind speed; and (2) various features of the urban structure, such as the size of cities, the density of the built-up areas, and the ratio of buildings' heights to the distances between them can have strong effect on the magnitude of the urban heat island.

Chandler [21], Landsberg [22] and Oke [23] noted that microclimatic effects of urban parameters on heat island are:

Table IV effect of urbanization on climatic parameters [2]

Climatic Parameter	**Effect of Urbanization**
Temperature	Rise in daily minimum temperature: Some change in maximum temperature.
Humidity	Reduction in daytime humidity, but increase in night-time values.
Precipitation	Large increases in summer (up to 21 percent) and smaller increases in winter (5-8 percent). In the tropics, the increase is attributed more to air pollution than heat emission.
Wind	Increases on the number of calm periods observed. Up to 20 percent reduction in wind speeds are known. The effect is greater upon weaker winds.
Solar Radiation	Though incoming radiation values are not changed, the apparent values are high due to the containment of reflected radiation by the heat dome.

population size, topography, rivers and other water bodies, wind speed, anthropogenic heat, water runoff and vegetation cover.

Therefore, as also put forward in conceptual model, UHI is the mutual response of many factors which can be divided into two factors: (1) meteorological factors; and (2) urban structure factors. This paper will be only focused on urbanization factors in Tehran metropolitan area.

A. *Tehran Urbanization Factors*

Increasing urbanization and industrialization has caused the urban environment to deteriorate. Deficiencies in development control have important consequences for the urban climate and the environmental efficiency of buildings. The size of housing plots has been reduced, thus increasing densities and the potential for traffic congestion. The increasing numbers of buildings have crowded out vegetation and trees [3]. As a matter of fact, many features of the physical structure of the city can affect the urban climate and with negative impacts lead to increase UHI intensity. As shown in Table IV, urbanization can directly affect climatic parameters such as temperature, humidity, precipitation, wind and solar radiation.

Therefore, it is important to describe the mean features by which the urban climate differs from the climatic conditions of the surrounding rural areas. The general effects of urban structure on its climate can be divided in the several groups described in the following way:\

A. Location of the City

Different locations within a given region may vary greatly in their temperature, wind conditions, humidity, precipitation, fog, inversion prevalence and so on. Such variations may be caused by differences in distance from the sea, altitude, direction of slopes, and the general topography of the area [5].

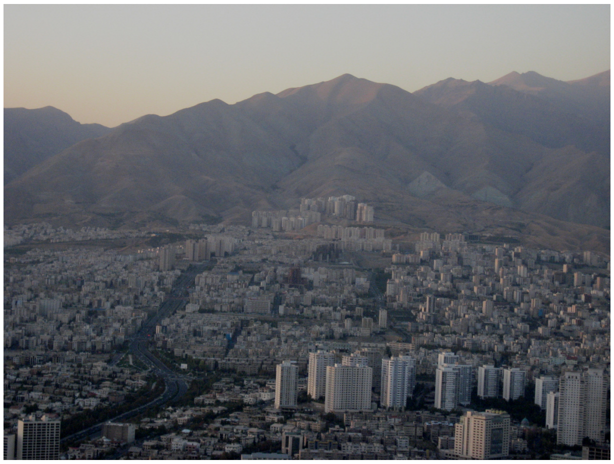


Fig. 13 north mountains in Tehran act as obstacles and aggregate pollutions

The existing of *mountain ranges* in the city can directly affect the formation of UHI. In Tehran city, north and east mountains prevent taking out the air pollution which is brought by west prevailing wind into the urban spaces and it is caused to pollutant the weather especially in east and central areas and increase inversion in Tehran (Fig. 13).

According to Givoni [5], local variations in *topography* may affect greatly the wind conditions. Windward slopes of a hill experience much higher wind speeds than the leeward slopes. A flat valley surrounded by mountains may experience poor ventilation conditions, a high frequency of nightly temperature inversions, and the associated likelihood of air pollution. A narrow valley facing the wind concentrates the airflow and the inhabitants, especially in cold regions, may suffer from excessive wind speed. On the other hand, in warm-humid regions, where natural ventilation is essential for comfort and where the general wind speed may be rather low, such windier locations may be the desirable ones.

In Tehran, topography condition, from north to south, increases pollution and provides warm air canopy over the central city and absorbs pollutions from the other parts of the city [24] .

B. The Size of the City and Population

Moving the large number of population from the suburbs to the urban areas are caused accelerating of urbanization and increasing the size of the city. The formation of the UHI phenomenon depends upon the size and density of the population, as well as of its standard of living (such as vehicular traffic, intensity of heating in the winter and air conditioning in the summer, and industrial plants). As described before Oke [23] has correlated the UHI intensity to the size of the urban population. They have a direct relationship which with higher population, the UHI intensity will be increased.

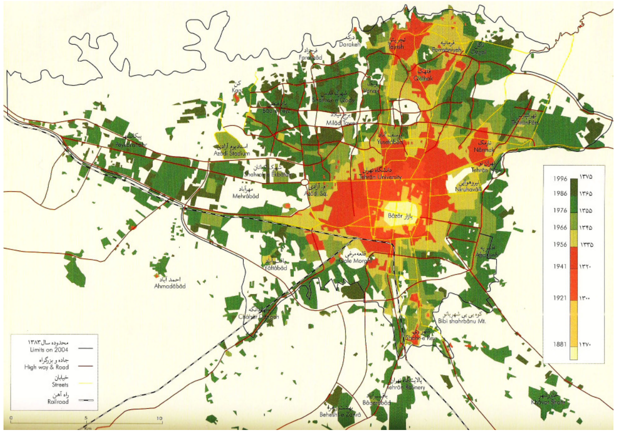


Fig. 14 the evolution of built-up areas in Tehran [25]

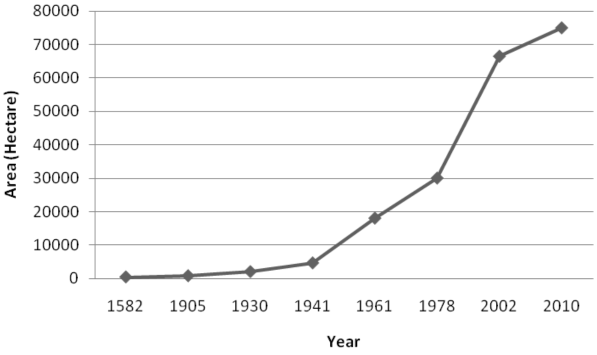


Fig. 15 physical development of Tehran city during different periods of time

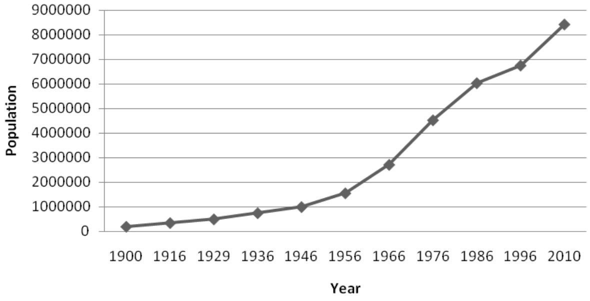


Fig. 16 population growth during different periods of time

The built environment of Tehran has changed considerably since becoming the capital of Iran more than 200 years ago. Fig. 14 shows the evolution of built-up areas in Tehran from 1881 to 1996. In this way, the urban area not only has been grown rapidly from 18.4 km^2 in 1869 to 750 km^2 in 2010 (Fig. 15), but also urban population has dramatically increased as shown in Fig. 16.

C. Density of Built-up Area

Density of the various built-up areas in a city affects the local climate in each of the discrete urban areas. In Tehran, accelerating of urbanization in order to comply demands of large number of population is caused increasing the density of built-up area which leads to raised temperature and the UHI intensity.

Buildings modify the wind, the radiant balance, and the temperature conditions near the ground level. Land covered by buildings cannot be planted. Therefore, the fraction of land covered by buildings in a given area is a relevant factor in evaluating the climatic effect of urbanization.

In addition, the distances between buildings along axis affect the solar exposure of the buildings and the potential for day lighting and for solar energy utilization for space and water heating (Fig. 17).

D. Urban Geometry

The urban geometry of a city is characterized by a repetitive element called the urban canyon [2]. Air circulation and temperature distribution within urban canyons are significant for the energy consumption of buildings, pollutant dispersion studies, heat and mass exchange between the buildings and the canyon air [3].

Fig. 17 high density of built-up areas in the central Tehran

Emmanuel [2] has defined urban canyon as the three-dimensional space bounded by a street and the buildings that abut the street. Urban canyons restrict the view of the sky dome (characterized by the sky view factor SVF), cause multiple reflection of solar radiation, and generally restrict the free movement of air (Fig. 18). For long urban canyons it is customary to specify the geometry by its height of building/width of street (H: W) ratio, sometimes known as the aspect ratio. Oke [11] believes that the sky view factor is a geometrical concept that describes the fraction of the overlying hemisphere occupied by the sky. Since the view of the sky is critical for long-wave radiation (as well as short-wave energy gain), it goes without saying that SVF is of critical utility to urban and increase UHI intensity.

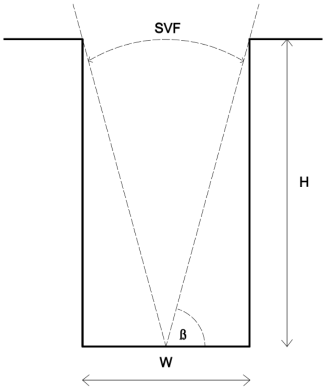


Fig. 18 canyon geometry and SVF

In Tehran city, complex urban geometry especially in the Central Tehran increases friction created by a rough urban

Fig. 19 urban geometry of the central Tehran

E. Thermal Properties of Fabric

Materials such as stone, concrete, and asphalt tend to trap heat at the surface [22], [21], [26]. These kinds of materials absorb and retain solar radiation in urban fabric and at night, this stored heat is released slowly from the urban surface.

The albedo of a surface is responsible for the amount of solar radiation it absorbs. High albedo building surfaces (such as white ones) have been proven to cool down urban temperatures [27], [28], [29].

In Tehran, the most of urban construction materials are concrete and asphalt with low albedo and non-reflective surfaces which absorb solar radiation and cause higher temperature and UHI formation (Fig. 20).

Fig. 20 urban construction materials in Tehran

F. Surface Waterproofing

Lack of porosity materials in urban surface, a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetated and moisture trapping surface create an evaporation deficit in the city caused intensity of urban heat island. Vegetation, especially in the presence of high moisture levels, plays a key role in the regulation of surface temperatures; even more than may non-reflective or low-albedo surfaces [30] and a lack of vegetation reduces heat lost due to evapotranspiration [31].

In Tehran, construction of new buildings has crowded out the vegetation. Destroying vegetation and green spaces has been caused the lack of evapotraspiration and higher temperature (Fig. 21).

Fig. 21 lack of porosity materials in Tehran urban spaces

G. Anthropogenic Heat

Anthropogenic heat into the urban atmosphere further contributes to the intensity of the UHI effect [28]. Urban centers tend to have higher energy demands than surrounding areas as a result of their high population density. Though the UHI effect reduces the need for heating in the winter, this is outweighed by the increased demand for air-conditioning

during the summer months [22], which in turn causes increased local and regional air pollution through fossil-fuel burning electric power generation. The pollution created by emissions from power generation increases absorption of radiation in the boundary layer [23] and contributes to the creation of inversion layers. Inversion layers prevent rising air from cooling at the normal rate and slow the dispersion of pollutants produced in urban areas [32].

In Tehran, increasing large number of buildings and population are caused that all the energy consumed by air conditioning is eventually released to the environment, elevating the urban temperature.

H. Air Pollution

In general, urban areas are subject to a wide range of pollutants. Three sources are the most important sources of air pollutants which include industry, motor vehicles and the burning of fossil fuels for heating or electricity generation. The contribution of industrial sources to air pollution varies considerably from one town to another, depending on the density and type of industry in an area, its precise location and the extent to which it has adopted restricting measures to control emissions or disperse them over long distances. In many cases, industrial pollution is exclusively an urban problem. On the other hand, air pollution problems related to city transport and buildings are more closely linked to the internal functioning of the city [3]. The contribution of these energy-using activities to the levels of particular pollutants is set out in Table V.

Table V sources of air pollution [3]

Sector	CO2	SO2	NOx
Energy generation	37.5	71.3	28.1
Industry	18.6	15.4	7.9
Transport	22.0	4.0	57.7
Others	21.9	9.3	6.3

Depending on the energy source, space heating can be one of the most important sources of air pollution. In Dublin, for example, domestic heating is a major source of SO2 and particulate. A gradual shift away from coal has removed some of the worst effects of particulate and SO2 pollution on a local scale. However, a shift to electricity does not solve the problem at the global level, owing to the pollution resulting from forms of electricity generation. In this wider global perspective, the use of all forms of fossil fuel contributes to problems of acid rain and, indirectly, to the greenhouse effect [3].

While the worst problems of local air pollution caused by heating have been solved, they have been replaced by increased levels of transport pollution. Automobile engines are major sources of NOx, CO, particulates and lead. As far as CO2 is concerned, it is worth noting that almost half of transport combustion is estimated to be due to urban traffic, while in many cities, the transport sector is responsible for almost 90% of carbon monoxide emissions.

Air pollutants, such as sulphur and nitrogen oxides, can be transported over long distances downwind from the released position. These pollutants either reaches the surface in dry form (dry deposition) or are removed from the air and carried to the ground by means of rain or snow (wet deposition or acid rain). Acid deposition contains both dry and wet deposition. Sulphur dioxide and oxide of nitrogen that are on the ground are transformed into acids interesting with the water. In addition, the air pollutants remaining aloft may be transformed into drops of sulphuric acid (H2SO4) and nitric acid (HNO3) and fall to the earth. As a result of this toxic precipitation, different areas of the world become acidic, causing severe effects on the natural environment.

The foundations of structures, building surfaces, monuments and other structures in many cities have been seriously affected. This is a major environmental problem that will become much more serious if adequate precautions are not taken.

It is known that between 65 to 70 percent of total emissions are related to urban transport operations [33]. The problem is compounded by topographical (mountains to the north and the east) and climatological factors (sunshine, frequent temperature inversions), which favor photochemical transformation of volatile organic compounds (VOCs) and nitrogen oxides (NOx) to produce smog and tropospheric ozone (Fig. 22).

Fig. 22 air pollution in Tehran

I. Land Uses

Industrial land uses in the west of Tehran are caused lots of problems. Settling industry in unsuitable place and not considering hygiene rules are caused Tehran air pollution and west and south western prevailing winds lead factories surplus materials to the city [33].

J. Wind Speed

Lower wind speeds in the city because of high density inhibit evaporation cooling and are caused warm air stagnates in the urban canyons and pollutions remain and increase the UHI intensity.

7 Conclusion

As observed, the percentage of UHI formation is high when great interaction exists. In fact, UHI measurements showed the urban areas have higher temperature than rural areas which is due to urban construction and materials. There is, therefore, a correlation between urbanization and climatic factors which they have direct impacts on the UHI formation.

In Tehran, especially in summers, raised temperatures derive from the altered thermal balances in urban spaces, mainly due to the materials and activities taking place in the city. The increasing numbers of buildings and construction in Tehran have crowded out vegetation and trees. Thus, air temperature increases especially in high density areas. The general lack of vegetation and the low albedo of urban surfaces are strong characteristics of the formation of the UHI effect in Tehran metropolitan area. The geometry between a vegetated area and the density-morphology of an urban area are completely different, which has a direct effect on wind and shade distributions. Human activities taking place in Tehran urban areas are responsible for anthropogenic heat release (transport, space and water heating, cooling and etc.) and air pollution, the latter affecting clouds cover [34]. The combination of these factors determines the way in which heat is absorbed, stored, released and dispersed in the urban environment, expressed as a temperature increase in the urban area.

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