The University of Tehran Press

Pollution

https://jpoll.ut.ac.ir/

Print ISSN: 2383-451X
Online ISSN: 2383-4501

Investigating the Effects of Urban Green infrastructure on Reducing the Heat Island Phenomenon in Shiraz Metropolis

Keramatollah Ziari[1] | Majid Golzar[2] ✉ | Hossein Iraji[1]

1. Department of Human Geography and Planning, Faculty of Geography, University of Tehran, Iran
2. PhD Student of Spatial Planning, Caspian International Campus, University of Tehran, Iran

Article Info

Article type:
Research Article

Article history:
Received: 13 July 2024
Revised: 14 September 2024
Accepted: 02 November 2024

Keywords:
Green infrastructure
Thermal islands
landscape
Shiraz

ABSTRACT

Today, the per capita green space in Shiraz metropolis is decreasing due to the increasing physical expansion and frequent land use change. The purpose of this research is to investigate the effects of urban green infrastructure on the reduction of the heat island phenomsenon of Shiraz metropolis through the processing of Landsat 8 satellite images by Fragstats and Arc Gis 10.3 software, which are compiled through the two processes of landscape metrics and the preparation of LST maps. Is. Based on the findings of land surface metrics, human land use at the land surface level of each region shows that districts 11, 4 and 5 of Shiraz city have the highest percentage of human-made land use. On the other hand, the 10th and 3rd regions have the least man-made land use. The results show that in areas 3, 6 and 11 of Shiraz city, there is high temperature resulting from human activities, which indicates the existence of thermal islands. The highest temperature is related to the area of Bagh Delgosha to the side of the coastal pass. The 11th and 9th district of Shiraz city has the best environmentally friendly form with a design method more compatible with the environment in the south-eastern direction, and the difference between the highest and the lowest temperature does not reach 20 degrees Celsius. Therefore, the existence of urban green spaces play an effective role in reducing heat islands.

Cite this article: Ziari, K. ,Golzar, M., & Iraji, H. (2025). Investigating the Effects of Urban Green infrastructure on Reducing the Heat Island Phenomenon in Shiraz Metropolis. *Pollution*, 11(2), 394-410.
https://doi.org/10.22059/poll.2024.379369.2465

DOI: https://doi.org/10.22059/poll.2024.379369.2465

INTRODUCTION

Today, following the increase in urbanization to more than 55% of the world's population, it has put more pressure on the environment (World Bank, 2022). Because increasing urbanization means using more resources and energy to meet the needs of human society, which has caused environmental challenges such as climate change, long-term droughts, and global temperature rise (Haixia Zhao et al, 2024). It is predicted that the temperature of the earth's surface will exceed 1.5 degrees Celsius during the years 2030 to 2052 (Battista, 2023). Despite the fact that cities occupy less than 2% of the earth's surface, they consume about 78% of the world's energy and produce more than 60% of the total carbon dioxide and significant amounts of greenhouse gases. Carbon dioxide is the main greenhouse gas that warms the earth's atmosphere (Ziari et al, 2023). The physical expansion of today's cities following the increase in urbanization has led to an increase in the use of personal vehicles. So that in some cities, traffic is considered as the second main cause of air pollution and urban heat (Aijia Wang et al, 2024). Therefore, it can be said that the existence of the urban heat island (UHI) is an indicator of the concentration of human activities, population growth and the excessive expansion of the urban built environment

*Corresponding Author Email: *majid.golzar@ut.ac.ir*

(Wang, 2024). Urban heat island (UHI) refers to the higher temperature of cities compared to the surrounding areas and is one of the most obvious climate changes in urban areas caused by human changes in natural landscapes, such as changes in vegetation patterns and water bodies through fragmentation. becoming and becoming impenetrable surfaces. Increasing absorption and trapping of solar radiation in built urban tissues, increasing population density and the absence of green areas are the main factors in the formation of heat islands (Iungman, 2023). Therefore, the air temperature inside the urban area, which is mainly composed of building blocks and cars, is higher than other peri-urban areas. For example, based on studies, the daytime temperature in urban areas is about 13 to 17 degrees Celsius higher than the temperature in remote areas (EPA, 2022). During the last century, the average temperature of the earth has increased by 1 degree Celsius compared to the pre-industrial period due to the emission of greenhouse gases (GHG) resulting from human activities. The first efforts to prevent the spread of environmental challenges that can have many negative consequences go back to 1972, the United Nations Human Environment Conference in Stockholm. The important dimensions of this conference include the preservation of natural resources, human settlement, human health, and the territorial ecosystem, which appeared in the form of a new concept called sustainable development in 1987 in the report of the World Commission on Environment and Development (WCED) (UN, 2021). Sustainable development refers to development that meets current needs without threatening the ability of future generations to meet their needs (Xiaosen Du et al, 2024). Also The ways to achieve harmonious development with the principles of sustainability and spatial planning is to evaluate the ecological potential of the regions.(ziari,et al,2024). One of the 17 goals of sustainable development is the protection and restoration of terrestrial ecosystems and the creation of sustainable cities, which has become a necessity due to the ever-increasing expansion of the urban body. Creating urban green infrastructure as a provider of sustainable development goals can provide many ecosystem services such as carbon sequestration and reduction of heat islands and as natural, semi-natural and artificial networks containing multi-purpose ecological systems in and around urban areas. (Yanbing Liu et al, 2024). Green infrastructure encourages the development and protection of green spaces through the integration of rural landscapes in the urban environment and supports productive economic activities and social dynamics by creating multipurpose green spaces (Tao Lin et al, 2024). During recent decades in developing countries, due to the existence of rapid urbanization, the physical growth of cities has increased, which will lead to the loss of agricultural lands around cities and the lack of urban green spaces due to the increase in housing demand for citizens. On the other hand, the existence of industrial factories and the use of non-standard means of transportation, which are the sources of urban environmental pollution, have significantly increased the emission of greenhouse gases, which can affect the health of living organisms. and cause a decline in the quality of urban life. Due to being located in a dry and semi-arid region, Iran has faced a shortage of water resources in recent years. Meanwhile, due to successive droughts, the amount of migration from villages to cities has increased, which has made cities face many environmental challenges. Shiraz metropolis also faces a lack of urban green space due to the increase of indiscriminate constructions and the existence of water stress in this area has made the lack of urban green space critical. On the other hand, the study of its temperature shows that the average temperature of Shiraz metropolis has increased compared to previous years. Based on this, the aim of this research is to investigate the role of urban green infrastructures such as parks, greening unused urban spaces on the reduction of heat islands.

MATERIAL AND METHODS

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development, which includes 17 goals. Addressing global challenges for people, planet, peace, prosperity and partnership were among its goals. Following that, in the framework of the 2030 Agenda, "Cities and Sustainable Urban Communities" was formed with the aim of creating inclusive, safe, resilient and sustainable cities (Vanessa G. Lo Iacono Ferreira et al, 2022).

The main areas of sustainable cities are (UNEP, 2022):

1) Providing a sustainable consumption and production policy for cities that covers all sectors

2) Interventions by government and urban planners through policy, technology and financing to reduce and manage pollution and waste

3) The participation of private sectors and stakeholders in creating a sustainable city

Urban sustainability can be defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Defined (siemens). In fact, ecologically sustainable cities are mainly based on the use of technologies to create an eco-friendly city. Specifically, a sustainable city seeks to maximize energy and resource efficiency, create a waste-free production system, support the production and use of renewable energy, promote carbon neutrality, and minimize environmental pollution. In addition, it reduces transportation needs and encourages walking and cycling and ensures efficient and sustainable transportation (Kateryna. K et al, 2021). In order to create more sustainable urban areas, according to the strategy of the European Union, urban green infrastructure is defined as a key tool for spatial planning that should support the protection of biodiversity and nature-based solutions. The concepts of bioeconomy, sustainable development and green and blue growth are the main elements of the current environmental program in Europe (Barbesgaard, 2020). Also, concepts such as the effects of urbanization on hydrology based on sustainable development in different countries, low-impact development (USA), water-sensitive urban design (Australia), the concept of the sponge city (China) or sustainable urban drainage systems (UK). They are mainly developed in industrialized countries (Fletcher et al 2015). These terms express the long-term conflicts between economic growth and environmental protection, which are adopted through consensus policies, and the purpose of which is to link various programs, including economic and social, with environmental concerns in decision-making processes. Green open space is one of the important components of the environment as the main element of urban spatial planning, which has a major impact on people's well-being (Wahyudi, 2023). The set of green open spaces and natural landscapes inside the cities is very necessary to prevent urban warming. This is considered important when there is little green space (vegetation) in the city limits. Because vegetation can play a role in balancing its temperature in addition to improving air quality. Vegetation, through the creation of urban green infrastructure, can take steps towards solving the problems related to the dynamics of the flow of materials and energy, improving ecosystem services. Green infrastructure in a city is realized through the creation of home gardens, parks, green roofs, vertical green systems, urban forests. Urban green infrastructure is defined as a key tool for spatial planning that should support biodiversity protection and nature-based solutions (Barbesgaard, 2018). In fact, Zbigniew Grabowski defined green infrastructure as a tool to help It defines cities to achieve the goals of sustainability and resilience while improving the lives of urban residents (Grabowski, 2022). do not use and therefore target many communities for green improvement without their consent (Grabowski, 2023). Green belts are the creation of public parks and open spaces in industrial areas for recreational and ecological purposes in the 1850s (Geneletti & Zardo, 2016). Green infrastructure is a clear example of a concept and policy that reflects the above points. (Geneletti & Zardo, 2016).In general, the goals of urban green infrastructure are: ensuring the preservation and promotion of ecosystems, improving the quality of life, creating a low-carbon city (reducing pollution), protecting the soil, urban sustainability and resilience, and supporting the city. Smart, creating thermal comfort, beautifying the urban landscape. Among the principles of urban green infrastructure planning, we can mention the integration of green and gray infrastructure, creating interconnected green space networks,

Table 1. Definitions of Urban green Infrastructure from the point of view of Theorists

Definition of green infrastructure	Theorists
Green infrastructure planning represents progress in green, environmental, social and aesthetic planning, for this reason, today's green infrastructure planning not only aims to create, design and develop a network of green spaces (and water) in urban and rural environments, but also includes Implementation and management of nature-based solutions through the use of planning processes, approaches and certain policy themes (Ferreira, 2021).	**Rall et al**
Green infrastructure as natural systems and according to the concept of smart city have strategies that can guarantee the economic, environmental, health and social benefits of the society. These policies include the following: *Forests and urban forests *Engineered wetlands and water ponds *Green roofs and green walls *Parks, gardens and grass areas *Natural systems (interconnected grasslands, wetlands, valleys, waterways and coastal areas)	**GIO Group** “ Green Infrastructure Ontario”
Defines urban green infrastructure as "a strategic network that consists of natural and semi-natural areas that are designed and managed according to environmental characteristics to provide a wide range of ecosystem services" (Marando, 2022).	**European Commission**

Source: Authors, 2024

Table 2. Principles of urban green infrastructure planning

The principles of dealing with green structures	
Functional and structural networks of green areas ensure ecological and social connection at different levels	Connectivity
Diversity of ecosystem functions and services	Being multi-purpose
Combining green (and blue) spaces physically and functionally	Integration
All kinds of green, blue and open spaces	several objects
Principles of dealing with planning processes	
Everyone has access to green areas and can benefit from its benefits.	social inclusion
Different spatial and temporal scales are considered	Multiple scales
Collaboration between key actors, disciplines, departments	interdisciplinary

Source: Simeon Vaňo et al, 2021

providing and improving the functions of multiple infrastructures, and collaborative planning.

Urban green infrastructure plans to solve challenges related to urbanization and sustainability through the two main principles of connectivity and multi-purpose. The principles of integration and multiobjective address green structures and social inclusion, and multiscale and interdisciplinarity stabilize planning processes. Therefore, urban green infrastructure can be defined as a “strategic planning approach”.

Another concept related to urban green infrastructure is urban biophilic. The term biophilia was first coined by the social psychologist Erich Fromm (1964) to describe the “love of life” that explains two basic tendencies of living things: to live with external threats, to preserve life in the face of threats. In recent years, the biophilic approach to the concept of returning nature to the city has been proposed as a holistic approach to nature in urban environments through design. Biophilia is a term expressed by Harvard University professor, biologist and naturalist Edward Wilson in 1984 (Wim van der Knaap, 2021). In defining biophilia, Wilson examines the relationship between man and nature. He emphasized that biophilia is “man’s innate emotional dependence on other living beings” where “inherent tendency” represents “hereditary” characteristics. Meanwhile, as a “learning rule”, it provides a clear perspective for understanding nature (Weijie Zhong et al, 2022). Cities, which are one of the human creations, have a two-way relationship with nature. According to one of the objectives of sustainable

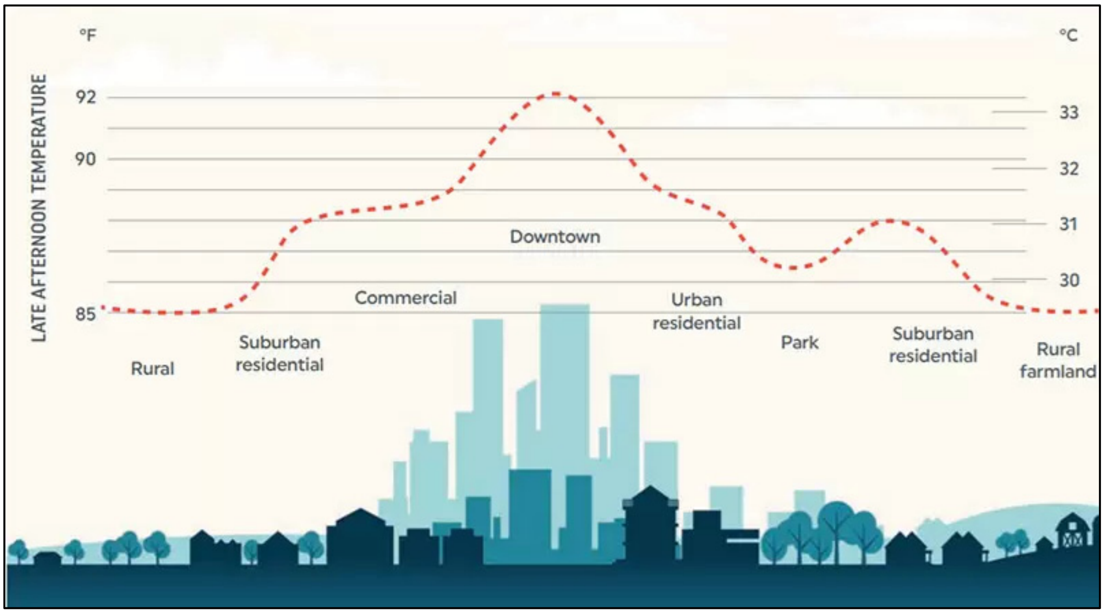

Fig. 1. urban view of thermal islands. Sources The Federation for Environment, Climate, and Technology (FECT), 2021

urban development, the city should keep pace with the environment. In this regard, Timothy Beatley in 2013 mentions cities in sync with the environment as biophilic cities (Beatley, T, 2017). Biophilic cities are a network of cities that not only pay attention to the physical characteristics of urban systems, but also include the behavior, knowledge and attitude of city dwellers towards nature (Beatley, T, Newman, P, 2013). In such cities, people care more about their surroundings and as a result have more understanding and communication with their surroundings. According to Batley and Newman, behavior ultimately increases resilience in cities. Bio-friendly urbanism, along with the concept of biophilic urbanism, commonly refers to the presence of nature in urban design (Kayıhan, 2018; Newman et al, 2017). The biophilic city is organized and implemented through urban planning actions and projects with the participation of city residents. Biophilic urbanism (BUI) measures include green infrastructure (such as parks, squares, green roofs, urban gardens, green belts), programs, policies, and government subsidies to create green spaces. In fact, biophilic urban planning measures are a wide set of activities through which to increase the correct relationship between people and nature and to take advantage of the natural landscape inside the cities (Virginia Carter et al, 2021). As mentioned, one of the consequences of urbanization is the physical expansion and increase in energy consumption in cities, which not only affects other urban dimensions, but also causes the phenomenon of heat islands. When the built surfaces on the ground surface increase due to the use of dark colors such as paving the streets and roofs of buildings, the amount of sunlight absorption and then the temperature of the surfaces will also increase. Urban heat islands refer to an area of the city that has a temperature difference with other places, which is mainly hotter (Dalaeli et al., 2022). For the first time, the term heat islands was proposed by Harvard in the book Climate of London. In this book, he believes that the creation of heat islands is caused by the absorption of sunlight by buildings and the surfaces of urban roads, and on the other hand, the lack of access to moisture for evaporation is another factor that plays an important role in creating the phenomenon of heat islands. After V-Ok, by calculating the ratio of the height of buildings to the width of urban roads, he achieved an experimental model to predict the maximization of thermal islands (Mahmoodzadeh et al., 2022).

In recent years, due to the phenomenon of urban warming, several researches have been conducted regarding the impact of urban green infrastructure on heat islands. Naseri et al. conducted a study in 2022 entitled "Evaluation of the effect of thermal islands of Ahvaz metropolis on the level of psychological comfort of citizens." From the results of this research, it can be pointed out that the heat tolerance threshold in the city of Ahvaz first causes an increase in daily stress and pressure in people, and then it leads to a decrease in happiness and life satisfaction in people (Nasseri et al., 2022). In a study, Azmir et al investigated the progress in green infrastructure for urban cooling. This study shows that for the successful integration of green infrastructure in the built environment, effective factors such as spatial distribution, microclimate and plant selection should be considered. Therefore, the integration of green infrastructure in cities should be comprehensively investigated and the common benefits and related exchanges should be considered (Amjad Azmeer et al, 2024). In another study, Chen investigated the role of spatial patterns of urban green infrastructure in temperature regulation. Based on the results of this study, it can be said that temperature differences in different urban areas depend on the distribution pattern of urban green spaces. In this way, the dense distribution of urban green infrastructure in a patchy manner has a significant impact on reducing urban heat islands. Meanwhile, in the scattered pattern, the deterrence power of urban green spaces in urban heating is significantly reduced. Therefore, the spatial pattern of urban green infrastructure plays an important role in regulating temperature and urban heating (Peng Chen, 2024). In a study, Min Wen Hee et al investigated the effect of green (blue, gray) infrastructure on high-density urban heat islands at multiple spatial scales in Wuhan, China. In this study, by extracting LST maps and land surface, the degree of correlation between urban green infrastructure and urban heating was also measured. The findings showed that according to the correlation tests, the effect of each of the green, blue and gray infrastructures has a significant difference in reducing urban heating. Thus, unlike gray infrastructure, green and blue infrastructures significantly reduce the amount of heat islands in cities (Minwen He et al, 2024). In another study, the use of urban green infrastructure to improve thermal comfort has been studied. Based on this, it was observed that there is a significant relationship between the presence of urban green infrastructure and thermal comfort of pedestrians in temperate, continental, dry and tropical climates. Considering the heat reduction effects, street trees, green spaces and green walls have a high cooling potential. According to the role of urban green infrastructure in the thermal comfort of pedestrians in different regions, it has been emphasized how to use suitable plants for each region (Bianca Milani de Quadros et al, 2023). According to the researches, there is a significant relationship between urban heat islands and the urban environment with dense vegetation. In fact, green spaces reduce urban heating through evaporation and absorption of short-wave radiation.

Knowing the Study Area

Shiraz Metropolis, as the capital of Fars province, is located in the south of Iran with a geographical position of 29 degrees 36 minutes north and 52 degrees 32 minutes at an altitude of 1484 meters above sea level. Its population is 1,957,694 people and its area is 217 square kilometers (Statistical Yearbook of Shiraz, 2021). Based on the measurements of Koppen, Amberje and Dumartin, Shiraz metropolis is located in a semi-arid region (Ketabchi et al., 2018). The annual average temperature of Shiraz metropolis is 18.6 degrees Celsius. On the other hand, the average water evaporation in this city according to the average annual temperature and the number of sunny days reaches 277.25 mm in 2020, which has increased by 108.13 mm compared to 2019 (Fig.3&4). Vegetation density is not uniformly distributed in the 11 districts of Shiraz city. Region 6 has the highest density of vegetation compared to other regions of Shiraz due to the existence of Qasr al-Dasht gardens. On the other hand, region 8 is physically dense and has the lowest amount of vegetation (Statistical Yearbook of Shiraz, 2022).

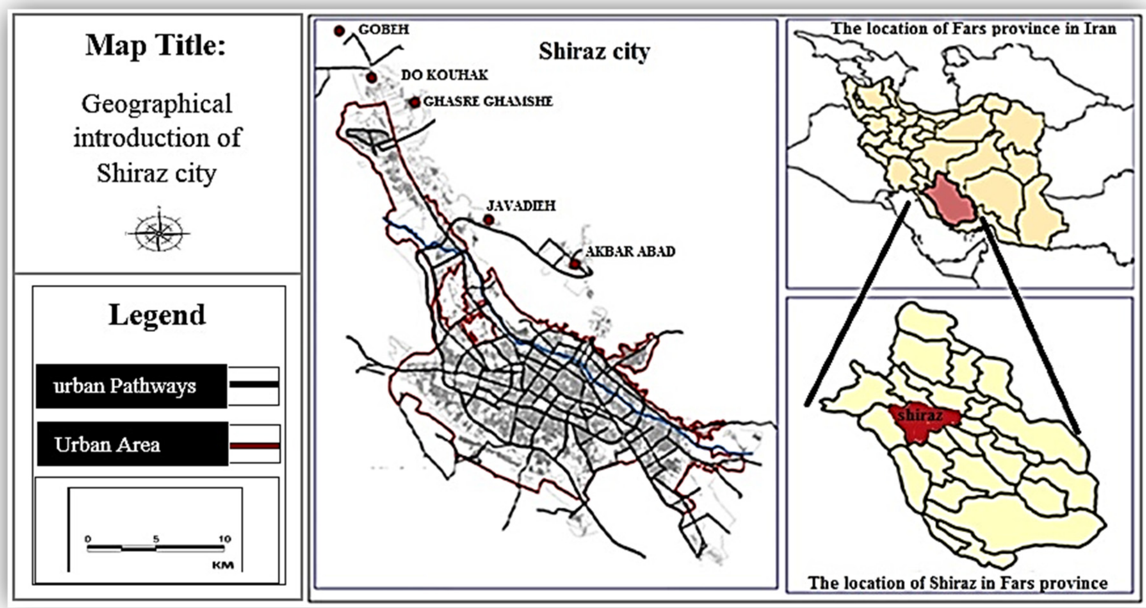

Fig. 2. Geographical Location of Shiraz Metropolis

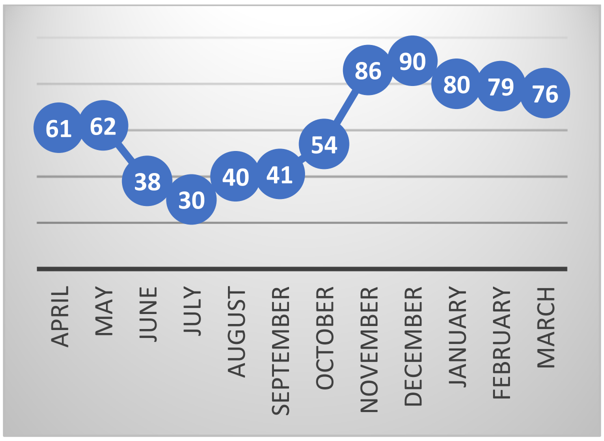

Fig. 3. Relative humidity percentage of Shiraz city 2021

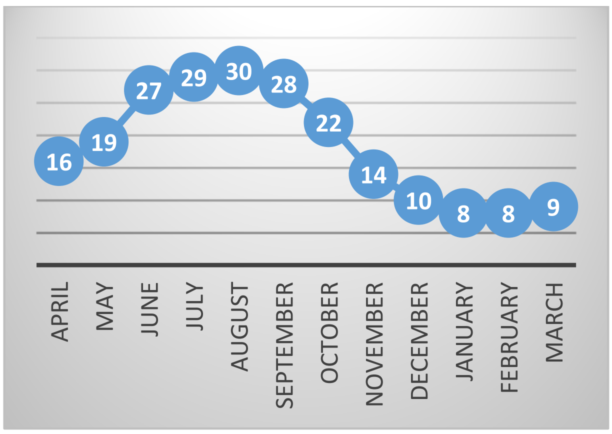

Fig. 4. Average temperature (0C) of Shiraz city 2021

Research Methodology

The upcoming research is applied in terms of purpose, in terms of descriptive-analytical methodology and based on remote sensing data and satellite images. In this way, he first obtained the satellite images of the Landsat 8 OLI sensor for 2020 from the USGS website, which has a spatial accuracy of 30 meters. ENVI 5.3 software was used to extract the 8 types of land use map, and in order to more accurately calculate the occupation level of each of the land uses, geometric and radiometric corrections were made on the satellite images. Then, the supervised classification method is used to classify the satellite image. In this method, a user is considered for each spectrum of color using the ROI tool, which is called sampling. After sampling and validation, a user map is extracted from it. In the second phase of the research, the thermal maps of Shahez Shiraz are prepared. In this phase, the satellite image of the Landsat 8 OLI sensor is entered into the Arc Gis 10.3 software environment, and after mathematical operations in the Rater Calculator plugin, the temperature of different surfaces is obtained. In the third phase, the morphological pattern of each urban area is investigated using Fragstats 4.2 software. In fact, the pattern of the city structure is quantified using landscape metrics. Land surface temperature (LST) is one of the most important parameters governing the physical, chemical and biological processes of the earth (Aliihsan Sekertekin, 2021). This index has a direct relationship with the amount of vegetation. According to the reports, vegetation can absorb part of the solar energy before it reaches the ground and in this way it prevents the heating of the surface. Earth surface temperature can be obtained from Land Sat 8 Oli satellite images. The steps to prepare the LST map are as follows:

$$\mathrm{TOA_L} = \mathrm{M_L} * \mathrm{Q_{CAL}} + \mathrm{A_L}\mathrm{TOA_L} = \mathrm{M_L} * \mathrm{Q_{CAL}} + \mathrm{A_L}$$

M_L =Specific multiplicative scaling factor from RADIANCE MULT_BAND_x metadata, where x is the band number.

The value obtained is from the MTL metadata file.

Qcal = The bar is its or"cut".

AL = The value in the MTL metadata "Radiance_Add_Band_X", where X is the number of bands.

2. Lighting temperature (BT) is the next step. The equation used is:

$$\mathrm{BT} = \left(\frac{\mathrm{K_2}}{\ln\left(\frac{\mathrm{K_1}}{\mathrm{L}}\right) + 1}\right) - 273/15$$

K1&K2 = The transformation constants, contained in the metadata (K1_CONSTANT_BAND_x) and K2_CONSTANT_BAND_x) are applied to each band, 10 and 11.

The results are given in degrees Kelvin, if the user wants to convert it to degrees Celsius, the formula must include the value 273.15. This equation should be done by replacing the values of bands 10 and 11. As before, the result of this operation produces an output raster for each thermal band.

3. The following is to calculate the NDVI (Natural Difference Vegetation Index), for these bands 4 and 5 are used, using raster calculator, the equation is as follows:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}} = \frac{\mathrm{Band\ 5} - \mathrm{Band\ 4}}{\mathrm{Band\ 5} + \mathrm{Band\ 4}}$$

4 . The obtained data are needed to obtain the Vegetation Ratio (Pv), the next step. The degree of coverage or vegetation ratio is calculated with the following relationship:

$$PV = (\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}})^2$$

$NDVI_{max}$= Maximum values visible in "Table of MATLAB"
$NDVI_{min}$= Minimum values visible in "Table of MATLAB"

5. The amount of radiation, as the last step, with the raster calculator, the following equation is obtained:

$$E = mP_V + N$$

m= amount of emission of vegetation.
Pv =percentage of vegetation.
N =amount of soil emission.

6. Finally, the land surface temperature (LST) is applied by the equation:

$$LST = \frac{BT}{1 + W(\frac{BT}{P})} * LN\ (\varepsilon)$$

BT = lighting temperature (band 10 or 11 depending on the case).
W =length of emitted radiation (band 10 or 11 depending on the case).
P= constant value obtained by the formula h * c / s which is 1.438 when replacing the values.

RESULTS AND DISCUSSION

Land Use changes in Shiraz Metropolis

After the pre-processing stage, the classified images were prepared. The largest amount of land classes is related to the use of pasture with poor coverage, which covers an important part

Table 3. Land Metrics

Metric	**Description**
PLAND	Class area (CA) and landscape percentage (PLAND) are basic measures of landscape composition. Specifically, how much of the landscape is made up of a particular patch type. This is an important feature in a number of environmental applications.
LPI	The biggest spot on the screen that shows development.
LSI	It compared the amount of edge in a scene with what would be expected for a scene of the same size but with a simple geometric shape (square) and no internal edges. This is the basis of the Landscape Shape Index (LSI) and its normalized version (nLSI), which are described in the Aggregation Metrics section.
PAFRAC	The index as the fractal dimension of the environment area (PAFRAC) is subject to inappropriate results when the sample size is small, since this index uses regression analysis. In landscapes with only a few patches, it is not unusual to obtain values that greatly exceed the theoretical limits of this index. Therefore, this index is probably only useful if the sample size is large by weighting the patches according to their size, although these measures do not have the same interpretation or application as PAFRAC.
CPLAND	Percent core landscape (CPLAND) at class level. The latter index quantifies the core area in each patch type as a percentage of the total landscape area. For organisms that are strongly associated with patch interiors, this index can provide a better measure of availability than its counterpart.
NDCA	From an organism-oriented perspective, a patch may actually contain several isolated patches of suitable interior habitat, and it is more appropriate to consider separate core areas as separate patches. in general These indicators may be more useful than their counterparts if the most important area of the entire area is recognized, but the same ranges as their counterparts (number of patches) are subject to limitations because they are not standardized relative to area.
DCAD	If core area is more important than total area, these indices may be more useful than their counterparts, but are subject to the same limitations as their counterparts (number of patches), as they are not standardized relative to area. For this reason, the number of core areas per unit area can be reported as core disaggregated area density (DCAD), which has the same ecological utility as its counterpart (patch density), except that all edge area is removed.
CLUMPY	The Clumpiness Index (CLUMPY) is just a class-level measure that is calculated from a maximum of -1 separated type to a maximum of 1 packing type divided by 1.

Source:Claudia K. Legarreta-Miranda et al, 2021

Table 4. The area of land uses in the Metropolitan area of Shiraz

Land use	land use Area
Poor coverage	101,676,64
pastures	24,155,36
Gardens and trees	14,471,40
Human beings	19,778,12
water sources	3,743,92
Fallow lands	11,576,44
Road robbery	6,683,84
Irrigation and rainfed agriculture	2,289,76

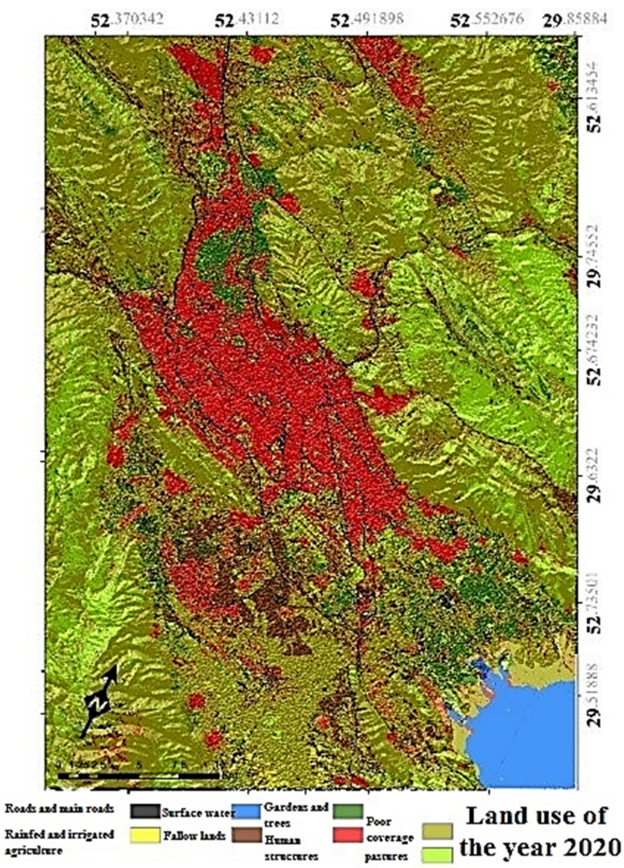

Fig. 5. Land use map

of the southwest of the city in the region, and includes more than 55% of the land in the area. After that, it includes areas of trees and a garden in the natural cover section. Therefore, rainfed and irrigated agriculture around the city has a major contribution in reducing the temperature around the city and creating diversity and providing food sources.

Temperature Pollution and heat Islands

Based on the results of the study of heat islands in Shiraz city, the existence of environmental structure is the first increasing factor on the increase in temperature of the city surface, and based on the analysis of the diagram, it was determined that there are heat islands and high temperatures resulting from human activities in regions 3, 6 and 11. The highest temperature is related to the area of Delgosha Garden to the side of the coastal pass, although the southern slope of the mountain is very effective in increasing its temperature. In region 4, there is the largest heat spot in the entire city of Shiraz. This area is related to the South Safir Blvd. to Bostan Irani and Imam Khomeini Street, which is the angle of urban design or the way buildings are arranged in the south direction and absorbs the maximum temperature of the sun. It is also an indicator of building density. And the instrument is 0.85. Region 11 and 9 with a design method more compatible with the environment in the south-east direction has the best environmentally compatible form and the difference between the highest and lowest temperature does not reach 20 degrees Celsius. In this regard, although the green structure of Region 1 has the most green coverage among other areas of Shiraz metropolis, it has a major and disproportionate structural weakness.

Green space form of Shiraz Metropolis

The importance of improving the biological and visual quality of the city with nature is the most important effect of green spaces in cities, which create a balance in the sustainable ecological processes of the city on the one hand, and promote and transfer the sense of beauty and nature on the other hand, increasing the biological quality of citizens. Green space has a positive effect on the quality of air pollution. In the whole area in 2019, the amount of green space is 49% of the surface area of roads and parks, indicating an attempt to establish a sustainable form of green in the city. This green space promotes the spiritual recovery of the community and the proximity of nature to the human habitat. District 1 of the municipality is considered a green zone and has played a positive role in attracting tourists and services throughout the region. Region 8 of Shiraz municipality has the lowest amount of green space due to the high residential density and until the present period it still has the lowest amount of coverage.

Landscape Metrics

Different Urban forms are Analyzed and evaluated based on design and planning concepts in order to provide a sustainable city form matrix with the help of urban planners and managers.

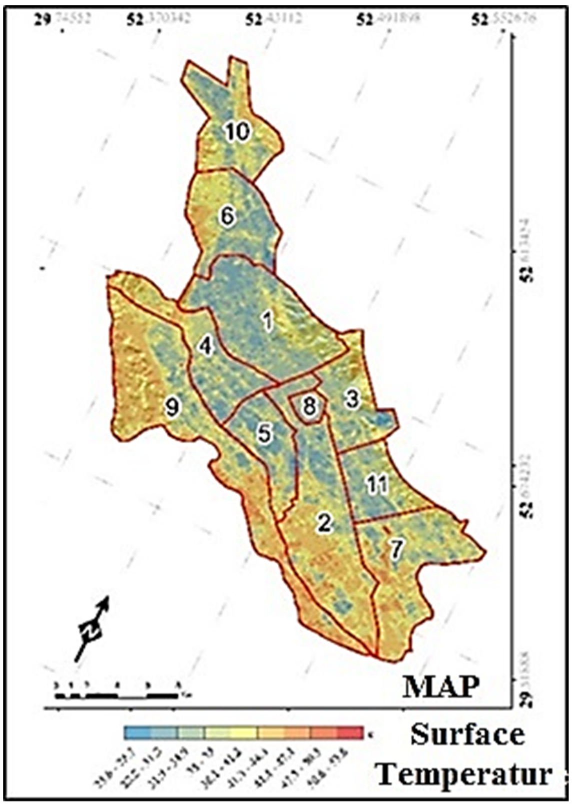

Fig. 6. Map of thermal islands in the city of Shiraz

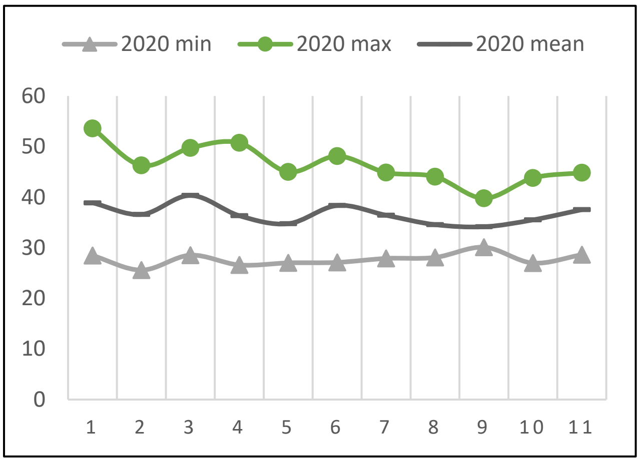

Fig. 7. Temperature chart at the level of 11 districts of Shiraz city

Table 5. Per capita changes in green cover in the city of Shiraz

Areas	Green space per capita
1	0.182
2	0.140
3	0.120
4	0.120
5	0.105
6	0.174
7	0.179
8	0.092
9	0.131
10	0.140
11	0.117

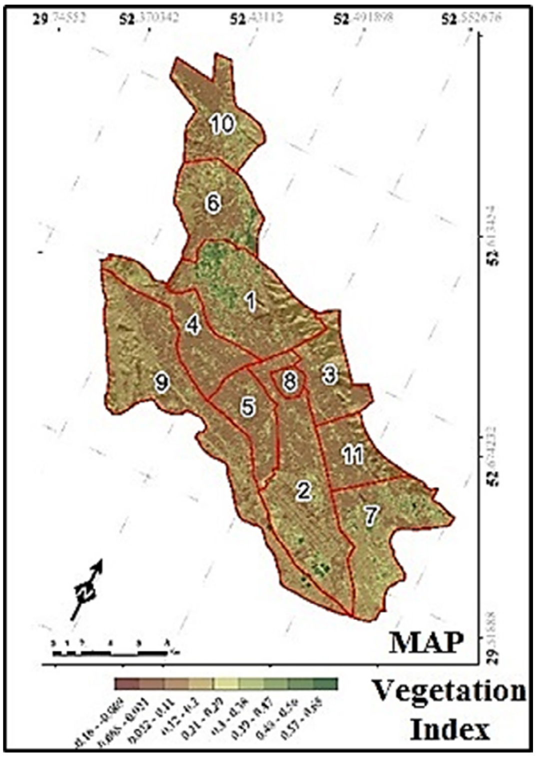

Fig. 8. Green space distribution map in Shiraz city

Landscape analysis is one of the most suitable metrics for evaluating the sustainability characteristics of urban forms. The design concepts of urban forms have been summarized in the following 8 indicators, which the results show. The first landscape metric is the presence or density of urban spots in the 11 metropolitan areas of Shiraz. According to human land use in each region, it shows that regions 11, 4 and 5 have the highest percentage of man-made land use. In contrast, regions 10 and 3 have the least man-made use due to the new appearance of the regions and settlement. However, it is expected that with the passage of time there will be a coordination between the 11 districts of Shiraz metropolis. In the study of the marginal density form and the linear growth of the urban landscape in region 6, the most marginalization or, in simpler terms, development has been done along the lines of communication, which has caused the elimination of fair access to transit and transportation routes, increased costs, and decreased It will save time and energy. On the other hand, region three has acted more appropriately by increasing condensation and forming more stable forms. It is necessary to mention that the limited topographical position of the third region has prevented dispersion, but in the sixth region, due to the presence of lands along the long road, this phenomenon has occurred. The discussion of density is based on the PAFRAC index, which specifies in which sector concentration and centrality are pursued more seriously. The average of this unit has increased for many years, and as a result, the transition from the pattern of building villas to horizontal development can be seen in all parts of Shiraz metropolis, and the average index for 2019 shows a value of 1.33, except for zone 5. Shiraz, which includes the segment of middle-class people from an economic point of view, has the lowest rate of 1.27 for this index. In order to check the division of the core and to know the population centers, it is necessary to look at the DCAD metric, the results of this index determine. The form of centralization and compression is decreasing from the city level and in general this index is facing a big decrease. In this regard, in terms of the development of service and economic cores, Region 3 of Shiraz has a better historical background, and the development or increase of core density and centrality has been maintained. In fact, a stable pattern of development can be seen in this region. The results of the analyzes for the CLUMPY index, which in a way reflects the creation of independent forms of each region in the metropolis of Shiraz; This index shows a kind of suitability of the infrastructures to solve or compensate the population and organizations. Therefore, according to the results of region 3, based on all the forms in the recent index, as the best point in Shiraz metropolis, it has a high self-sufficiency in solving infrastructure problems, although the infrastructure design method with a score of 0.91 is far from the best. The condition of this indicator is that one of the important factors of this issue is the structure and the interweaving of all the necessary infrastructures, including green space, city furniture, services, tourism and tourist, as well as communication ways such as the subway.

In addition to the upcoming research, many internal and external studies have been conducted in the field of heat islands of cities and the role of green spaces in reducing them. Ahmadi et al., by investigating the effect of land use and vegetation on the formation of thermal islands in Qain city, found that the changes in land use area between 2000 and 2010, the land use area of built-up areas, agriculture and gardens increased, and the area of barren lands and pastures decreased. Is. Considering the importance of vegetation and its role in adjusting the temperature of the earth's surface, in the areas with dense and rich vegetation, the temperature has been decreasing, considering that most of the agricultural land in the area around the city is cultivated with saffron, which is grown in the hot seasons of the year. It also lacks surface cover, so changes in the type of cultivation can have a significant impact on the temperature of the earth's surface (Ahmadi & Azadi Mubaraki, 2019). Also, the spatial analysis of the thermal islands of Qom city as a profile of the urban environment, which was done by Zanganeh et al., it is possible to get the highest temperature related to the barren lands around the city and the lowest temperature related to the areas containing vegetation and green spaces. have been; In

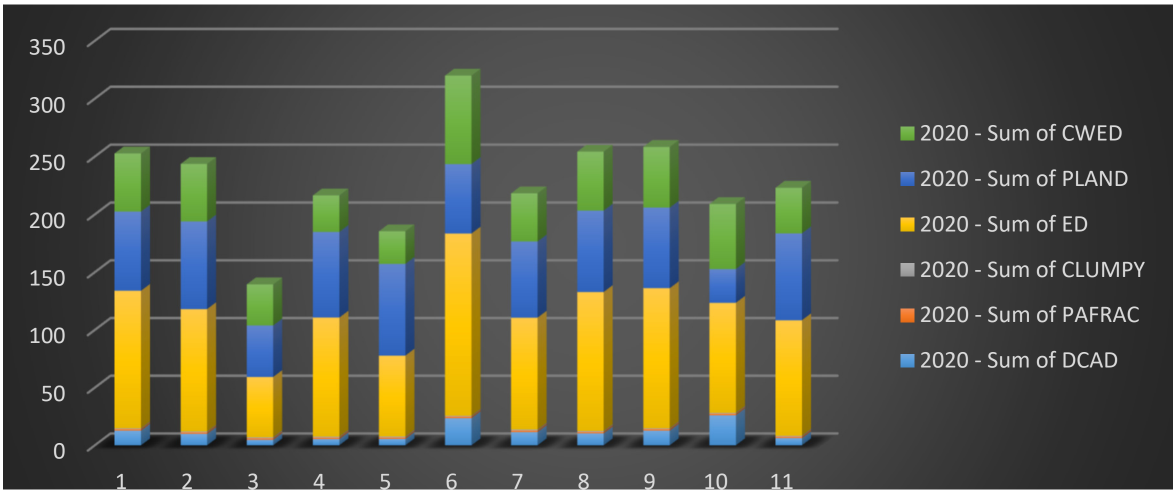

Fig. 9. Analysis of various parameters of Shiraz metropolitan area

other words, a hot thermal peninsula was formed in the outskirts of the city and cold thermal islands in the center of the city during the study period (Zanganeh et al., 2022). One of the foreign studies conducted in the field of urban heating can be mentioned the effect of seasonal land cover in creating a heat island in the urban area of Wuhan, China. The findings showed that there is always a direct relationship between land cover and the temperature of its surfaces. Therefore, lands with vegetation show lower temperature than other lands (Shihui et al., 2023). In addition, in another study, it has been shown that the presence of trees on the sides of the street can reduce the temperature by up to 6 degrees Celsius (Chang et al., 2023).

CONCLUSION

Today, many cities face many challenges due to the intensification of human activities. One of the major challenges is the increase in temperature in cities due to frequent land use changes, excessive use of personal vehicles, and lack of urban green spaces. The existence of urban green infrastructure is used as a necessary thing to adjust air temperature, reduce runoff and beautify the landscape. In recent years, the metropolis of Shiraz has faced a per capita shortage of green spaces due to rapid physical growth, which has caused the formation of heat islands and an increase in urban temperatures in some urban areas. By examining the body and the amount of green space in Shiraz metropolis through Landsat 8 satellite images, area 6 has the most marginalization or, to put it more simply, development in line with communication lines, which causes the elimination of fair access to transit and transportation routes. increase in costs and decrease in saving time and energy. On the other hand, region three has acted more appropriately by increasing condensation and forming more stable forms. It should be noted that the limited topographical position of the third region has prevented dispersion, but this phenomenon has happened in the sixth region due to the presence of lands along the highway. The obtained results showed that the distribution of land uses in Shiraz metropolis does not have much difference compared to urban indicators and standards. In the 11 districts of Shiraz Municipality, the access and fair distribution of infrastructures in districts 4, 6 and 2 have an imbalance, among which, the concentration of places and cultural-religious infrastructures, access and distribution of transportation infrastructures, space Appropriate education, urban and tourism facilities have a more inappropriate spatial balance compared to other uses, based on the existence of the environmental structure, the increase in the temperature of the city surface is the first increasing factor, and on this basis, it was determined that in areas 3, 6 and 11, heat islands and high temperatures resulting from There are human activities. The highest temperature is related to the area of Delgosha Garden to the side of the coastal pass, although the southern slope of the mountain is very effective in increasing its temperature. In general, the results show that with the urban development of this area during the last 10 years, the temperature has increased by 8.9 degrees Celsius. Region 11 and 9 with a design method more compatible with the environment in the south-east direction has the best environmentally compatible form and the difference between the highest and lowest temperature does not reach 20 degrees Celsius. In this regard, although the green structure of Region 1 has the most green coverage among other areas of Shiraz metropolis, it has a major and disproportionate structural weakness. In general, based on the findings, it can be said that in an arid and semi-arid region such as Shiraz, which faces limited water resources, cooling devices such as water and gas coolers are unsuitable options for cooling. Therefore, by improving vegetation and urban green spaces, on the one hand, it helps thermal comfort, and on the other hand, it leads to the beautification of the urban landscape. Also, this research shows that the formation of heat islands can be caused by the urban structure and morphology. Because the findings show that the denser the city is and the less vegetation there is, the temperature of its surfaces will increase and vice versa.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

ACKNOWLEDGEMENT

We would like to thank the editorial board of the pollution journal for giving us the opportunity to present this research, and we are also grateful to the support of the University of Tehran for any kind of sincere cooperation.

REFERENCES

Ahmadi, M., & Azadi Mubaraki, M. (2019). Investigating thermal islands of Tabriz with urban livability approach. Earth Science Research, 11(3), 245-262. doi: 10.52547/esrj.11.3.245

Aijia,W., Junqi,W., Ruijun ,Z ., & Shi-Jie,C.(2024), Mitigating urban heat and air pollution considering green and transportation infrastructure, Transportation Research Part A: Policy and Practice, Volume 184 , June 2024, 104079.

Amjad,A., & Furqan,T (2024), Progress on green infrastructure for urban cooling: Evaluating techniques, design strategies, and benefits, Urban Climate.Volume 56, July 2024, 102077.

Anjoman Al-Shoa, F., Morovati, M., Tazeh, M., & Bahadori Amjaz, F. (2021). Investigating the relationship between thermal islands and green space boundaries and revealing its changes (case study: Kerman city). Geography and Environmental Sustainability (Geographic Research), 11(41), 83-106.. DOI: 10.22126/GES.2022.6836.2439

Barbesgaard , M., Barbesgaard,M., Stolz,D., & Thompson,B. (2019), In oceans we trust: Conservation, philanthropy, and the political economy of the Phoenix Islands Protected Area, Marine Policy Volume 107. https://doi.org/10.1016/j.

marpol.2019.01.010

Battista,G., Lieto,E., Ocłoń,P., & Lieto Vollaro,L. (2023), Corrigendum to “Effects of urban heat island mitigation strategies in an urban square: A numerical modelling and experimental investigation”, Energy and Building, Available online 30 . DOI:10.1016/j.enbuild.2023.113475

Beatley,T., Andrijcic, E., & Haimes Y.Y. (2013), Public policy implications of harmonizing engineering technology with socio-economic modeling: Application to transportation infrastructure management, Transportation Research Part A: Policy and Practice Volume 50, April 2013, Pages 62-73. https://doi.org/10.1016/j.tra.2013.01.027

Bianca,M., & Martin,G.(2023), Urban green infrastructures to improve pedestrian thermal comfort: A systematic review, Urban Forestry & Urban Greening Volume 88, October 2023, 128091.

Chang, Xi., Li,H., Junqi,W., Zhuangbo,F., Prashant,K., & Shi-Jie, C. (2023), How can greenery space mitigate urban heat island? An analysis of cooling effect, carbon sequestration, and nurturing cost at the street scale, Journal of Cleaner Production Volume 419, 20, https://doi.org/10.1016/j.jclepro.2023.138230

Dalaeli, R., Moradi, GH,R., & Dehghanian, M. (2022). Recognition and analysis of urban heat islands using Landsat 8 satellite image (case example: Shiraz city). Application of geographic information system and remote sensing in planning, 13(1), 30-49.

EPA,2022

Fletcher, S., Hunt, A., Butler, A., &Vik,l. (2014). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal, 12(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

Geneletti,D,.& Zardo,L. (2016), Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans, Land Use Policy Volume 50, January 2016, Pages 38-47. https://doi.org/10.1016/j.landusepol.2015.09.003

Grabowski,Z.(2022), A social-ecological-technological systems framework for urban ecosystem services, One Earth Volume 5, Issue 5, 20 May 2022, Pages 505-518. https://doi.org/10.1016/j.oneear.2022.04.007

Grabowski,Z.(2023), Why go green? Comparing rationales and planning criteria for green infrastructure in U.S. city plans, Landscape and Urban Planning Volume 237, September 2023 https://doi.org/10.1016/j.landurbplan.2023.104781

Haixia,Z., Binjie,G., Ling, Z., Xin ,Li., & Xiang,G.(2024), Evaluating the demand for urban green infrastructure: A residential perspective, Cities Volume 153 , October 2024, 105271

Iungman,T, MPH(2023), Cooling cities through urban green infrastructure: a health impact assessment of European cities, Volume 401, Issue 10376, 18–24 February 2023, Pages 577-589. https://doi.org/10.1016/S0140-6736(22)02585-5

Kateryna ,K., Kateryna K., Yurii K., Pavlo, K., & Cezar, M. (2021), World cities in terms of the sustainable development concept, Geography and Sustainability Volume 2, Issue 4, December 2021, Pages 304-311. https://doi.org/10.1016/j.geosus.2021.12.003

Claudia,K., Jesús,A., Federico,V.,Carlos,R., & Alfredo,P. (2021). Long-Term Land-Use/Land-Cover Change Increased the Landscape Heterogeneity of a Fragmented Temperate Forest in Mexico. Forests 2021, 12(8), 1099; Pages 1-14 https://doi.org/10.3390/f12081099

Kayıhan, K.S. (2018). Examination of Biophilia Phenomenon in the Context of Sustainable Architecture. In: Fırat, S., Kinuthia, J., Abu-Tair, A. (eds) Proceedings of 3rd International Sustainable Buildings Symposium (ISBS 2017). ISBS 2017. Lecture Notes in Civil Engineering , vol 6. Springer, Cham. https://doi.org/10.1007/978-3-319-63709-9_7

Ketabchi, E. & Resaiepour, M. (2019). Measurement of thermal islands in the border and middle of Shiraz metropolis with climate resilience approach and using data logger software. Architecture Exclusive Journal of Architecture and Urban Development of Iran, 8(2).

Mahmoudzadeh, H., & Amanzadeh, F.. (2022). A comparative study of heat island severity based on urban geometry (case study: Koi Valiasr and Shanb Ghazan neighborhoods in Tabriz). Human Geography Research, 54(2), 675-697. doi: 10.22059/jhgr.2021.311999.1008192

Minwen,H., &Chao,Y. (2023), Impacts of green-blue-grey infrastructures on high-density urban thermal environment at multiple spatial scales: A case study in Wuhan, Urban Climate Volume 52, November 2023, 101714

Nasseri, M., Safaipour, M., & Rezaei Jafari, K. (2022). Investigating the effect of thermal islands of Ahvaz metropolis on the level of psychological comfort of citizens. Quarterly Journal of Urban and Regional Sustainable Development Studies, 3(1), 1-22.

Shihui,Y., Zhigang, R., Xiaofang ,S., Qinli ,D., &Zeng ,Z.(2023), Seasonal different effects of land cover on urban heat island in Wuhan’s metropolitan area, Urban Climate Volume 49. https://doi.org/10.1016/j.uclim.2023.101547

Statistical yearbook of Shiraz city, (2021). Statistics Center of Iran.

Statistical yearbook of Shiraz city, (2022). Statistics Center of Iran.

Tao,Lin., &Jiayu,C. (2024), Incorporating suburban cropland into urban green infrastructure: A perspective of nature-based solutions in China, Nature-Based Solutions.Volume 5, June 2024, 100122

Yanbing,L., &Baolong, H.(2024), Uncovering the role of urban green infrastructure in carbon neutrality: A novel pathway from the urban green infrastructure and cooling power saving, Journal of Cleaner Production Volume 452 , 1 May 2024, 142193.

Vanesa ,G. Lo, Garcia-Bernabeu,A., Hilario-Caballero,A., &Torregrosa-López,J. (2022), Measuring urban sustainability performance through composite indicators for Spanish cities, Journal of Cleaner Production Volume 359, 20 . https://doi.org/10.1016/j.jclepro.2022.131982

Virginia,C., Ben D., & Cristián H. (2021), Assessing local governments' perception of the potential implementation of biophilic urbanism in Chile: A latent class approach, Land Use Policy Volume 101, February 2021. https://doi.org/10.1016/j.landusepol.2020.105103

UN, 2022

Wang,B., & Qingfeng,G (2024), Modeling the Subpixel Land-Use Dynamics and Its Influence on Urban Heat Islands: Impacts of Factors and Scale, and Population Exposure Risk, Sustainable Cities and Society Volume 107 , 15 July 2024, 105417.

Weijie,Z., Torsten, S., & Juliette,B. (2022), Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review, Frontiers of Architectural Research Volume 11, Issue 1, February 2022, Pages 114-141. https://doi.org/10.1016/j.foar.2021.07.006

Wim van, DK,. Bijandi, M, Karimi ,M., & Farhadi Bansouleh,B .(2021), A novel approach for multi-stakeholder agricultural land reallocation using agent-based modeling: A case study in Iran, Landscape and Urban Planning Volume 215, November 2021, https://doi.org/10.1016/j.landurbplan.2021.104231

World Bank, 2022

Xiaosen,D., &Jing,Z. (2024), Spatial effects and influencing factors of urban sustainable development: An analysis of urban agglomerations in China, Economic Analysis and Policy Volume 81 , March 2024, Pages 556-575.

Zanganeh, A, H., Ravanbakhsh, F., & Khosravi, Y. (2022). Spatial analysis of thermal islands of Qom city as a profile of urban environment. Geographical Explorations of Desert Regions, 10(2), 1-11. doi: 10.22034/grd.2022.17201.1501

Ziari, K., Zargham ,M., & Khademi,A,H. (2015), "Urban planning with a biophilic approach (nature-oriented city)." Tehran: Arad Ketab.IRAN.

Ziari,K., Alijani,S., Hatami Nejad,H., & Sodoudi,S. (2023), A new approach of urban livability in Tehran: Thermal comfort as a primitive indicator. Case study, district 22, Urban Climate Volume 33 , September 2020, 100656. DOI:10.29252/jsaeh.6.2.89

Ziari, K., Mansouri Etminan, A., & Golzar, M. (2024). Qeshm Geopark and an Evaluation of its Capabilities for Various Activities. Geopolitics Quarterly, 20(74), 323-349. doi: 10.22034/igq.2024.431873.1825