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Original Research Article

Investigating the Correlation between Blue-Green Infrastructure and Reduction of Heat-Related Health Effect Under Climate Change
Case Study: Qazvin City*

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Abstract

Problem statement: Climate change, especially the heating trend in recent decades, has increasingly affected human health and increased heat-related mortality and morbidity, mainly in cities. Implementing mitigation and adaptation strategies to climate change by managing blue-green infrastructure (BGI) can reduce the consequences of these changes. The research hypothesis is that increasing the BGI per capita in different city districts will reduce the temperature and the number of heat-related patients.

Research objective: This paper aims to compare the effect of two indicators of BGI to decrease temperature and health risks.

Research method: We chose Qazvin city as the case study, and selected heat-related diseases, heatstroke, cardiovascular disease, stroke, and respiratory (dependent variables). After that, the numbers of monthly ambulance calls for the four mentioned diseases (April 2018 to August 2020) were analyzed in all six Qazvin districts. Next, MODIS data were used to conduct Qazvin's surface UHI map during the mentioned period and show the BGI distribution on the city map, NDVI, as well as calculate the per capita and the percentage of the area of BGI (independent variables) in each city district by GIS. Then, We conducted a linear correlation analysis with the dependent and independent variables and employed Spearman's Rho as the correlation measure.

Conclusion: The results show an inverse correlation between BGI per capita and the number of ambulance calls for cardiovascular, stroke, and respiratory diseases. Molavi and Ferdowsi districts with the lowest BGI per capita and highest land surface temperature (LST) have the most patients, and Pardi's district with the highest BGI per capita and lowest LST have minimum patients. Such correlation is not valid for the percentage of the area of BGI. Therefore, urban landscape planning should pay more attention to the most densely populated districts to reduce health inequality due to climate change.

keywords: *Climate change, Blue-Green Infrastructure (BGI), Health, Global warming, Heat-related diseases.*

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Introduction

Environmental problems, especially climate change, have become the most critical global threat in recent decades. Climate change is due to global warming caused by the burning of fossil fuels and the emission of greenhouse gases. This change is increasingly, directly and indirectly, affecting human health. According to the World Health Organization, "Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year from malnutrition, malaria, diarrhea, and heat stress" (Watts et al., 2020, 31). Health vulnerabilities to climate change include various physical, physiological, and psychological effects (Murray & Ebi, 2012, 82). Many of the most common human diseases are linked to climate change, including cardiovascular and respiratory deaths due to heatwaves, as well as the transmission of infectious diseases and malnutrition (Patz, Campbell-Lendrum, Holloway & Foley, 2005). One of the main signs of climate change is the warming trend in recent decades. This trend has increased morbidity and mortality in many areas (ibid.) and has become a significant threat to citizens, especially vulnerable groups. There is a general agreement that extreme heat impacts human health, and extreme heatwaves increase premature death (Lelieveld et al., 2016, 256).

Some researches have shown that the increasingly detrimental effects of extreme heat on human thermal comfort lead to psychological vulnerabilities such as thermal sensation, mood, and concentration and physiological vulnerabilities such as sunburn, heatstroke, and heat cramps (Liu, Lian & Brown, 2019). Health statistics and meteorological data also show a clear correlation between high temperature and cardiovascular mortality from stroke, ischemic stroke, and other heart diseases. Therefore, extreme heat is the leading cause of premature death due to climate change (Lelieveld et al., 2016, 246). As a result, in recent years, both adaptation and mitigation to climate change and reducing Heat-related diseases, which lead to longer and healthier lives, have received more attention.

The consequences of global warmings, such as health risks, are more significant in cities. Rapid urbanization challenges in the world also increase health threats (WHO, 2019, 42). Similarly, the main goals of sustainable development also point to these important consequences. The sustainable development goals (SDGs) in health, environment and climate change include ensuring healthy lives and promoting wellbeing for all ages, creating comprehensive, safe, resilient, and sustainable cities and human settlements, and taking urgent action to combat climate change and its impacts. Thus, these are closely linked, and any change in any of these factors leads to some results in the others (ibid., 21-22). Thus, mitigation and adaptation to climate change are more important in cities. Adaptation generally refers to controlling the characteristics and processes to cope with adverse consequences of climatic change or taking advantage of possible opportunities (Tol, Fankhauser & Smith 1998; Smit, Burton, Klein & Wandel; Lim, Spanger-Siegfried, Burton, Malone & Huq, 2005). One of the principal adaptation actions is the implementation of nature-based solutions in urban areas. With regard to urban green and blue spaces, nature-based solutions can foster and simplify implementation actions in urban landscapes (Kabisch, Korn, Stadler & Bonn, 2017, 2). In addition to the numerous benefits of nature-based solutions in the urban landscape, they increasingly affect human health and wellbeing (Gehrels et al., 2016; Kabisch et al., 2017, 3) Therefore, in this study, the role of blue-green infrastructure is investigated as the main strategy to reduce temperature and increase health.

Theoretical framework

- **Green-blue infrastructure**

Blue-Green Infrastructure (BGI) includes all artificial, natural, and semi-natural components of coherent ecological networks in urban areas. The comprehensive definition put forward by Benedict and McMahon (Benedict & McMahon, 2002) is: "Green (blue) Infrastructure is an interconnected network of waterways, wetlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches, and forests; and wilderness and other open spaces that support species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life for communities and people" (Mell, 2008). Connectivity plays a central role in the concept of BGI (Faggian & Sposito, 2009; Faggian, Romeijin & Sposito, 2012). This concept is different from green spaces and blue spaces separately. Moreover, the critical role of Blue-Green Infrastructure in adapting and mitigating climate change impacts, especially extreme heat, has been known in recent years (Gill, Handley, Ennos & Pauleit, 2007; Kazmierczak & Carter 2010; Kabisch et al., 2017). This ability is due to the cooling potential of the green-blue infrastructure.

• **The role of Blue-Green infrastructure** (BGI) **in reducing temperature and improving health**

Improving heat-related health in the city can be achieved by identifying and analyzing the high-risk areas and redesigning the urban landscape in these areas. Microclimate modification in these areas can significantly improve outdoor thermal comfort. Therefore, citizens are less exposed to extreme heat, and heat-related mortality and morbidity are reduced. (Graham, Vanos, Kenny & Brown, 2017, 779; Liu, Lian & Brown, 2019, 1). In this regard, the design and planning of blue-green infrastructure as integrated ecological networks of urban landscape can contribute to adaptation to climate change, promoting and supporting healthy living (Gehrels et al., 2016). Therefore, blue-green infrastructure with micro-climate modification is known as a strategy to reduce heat and increase health.

So far, some authors have written many articles about the role of green spaces in reducing the effects of heat. Many studies have linked the increase in urban green areas to an effective decrease in temperature (Martinez, de'Donato & Kendrovski, 2021, 142). Similar to the mentioned research, other studies have examined the benefits of reducing heat load through urban water spaces, and the results are sometimes very different (ibid., 143). But there are few studies on the cooling effects of a combination of green infrastructure and blue infrastructure. The result of research in this area has shown that both green and blue spaces can effectively reduce urban heat. When both urban blue and green space characteristics are used together, they can enhance ecosystem benefits, including cooling. But few scientific papers explain the effect of this synergy (Antoszewski, Świerk, & Krzyżaniak, 2020).

Research background

In a recent World Health Organization (WHO) report titled "Heat and health in the WHO European Region: updated evidence for effective prevention," a chapter is devoted to long-term urban planning to reduce heat risks. This chapter emphasizes the urban green and blue infrastructure as the most important interventions to reduce overheating (Martinez, de'Donato & Kendrovski, 2021). While green spaces are the best form of urban planning intervention in mitigating heat, important questions will remain, limiting the ability to provide specific recommendations for practical planning and management (ibid., 143). These questions are related to several factors affecting the cooling of these infrastructures, such as geometry, type, size, connection (composition and configuration) of green and blue space, seasonal and daily differences, latitude, and climatic differences (Yu et al., 2020).

Although extensive research has been done on green space and temperature reduction, little research has been conducted in recent years on the correlation between green infrastructure and reduced heat-health vulnerability due to climate change. For example, an article entitled "The relationship between neighborhood tree canopy cover and heat-related ambulance calls during extreme heat events in Toronto, Canada" (Graham, Vanos, Kenny & Brown, 2016) explored the relationship between the amount of canopy cover from trees and the incidence of heat-related morbidity during extreme heat events in 544 neighborhoods of Toronto, in 3 years period. The results show that the number of heat-related ambulance calls in heatwave days has negatively correlated to tree canopy cover and positively correlated to hard surface cover. Also, another article entitled "Linking green infrastructure to urban heat and human health risk mitigation in Oslo, Norway" (Venter, Krog & Barton, 2020) found that monthly air temperatures significantly correlated to the number of skin-related diagnoses at the city level. Moreover, the results show that land surface temperatures were negatively related to tree canopy cover and vegetation greenness in areas composed of complete tree canopy cover or mixed (tree and grass) vegetation. Therefore, maintaining tree cover provides urban heat reduction and improves health. These articles emphasize the role of green space and do not consider the role of water space.

Besides, some articles have examined the effect of green space in reducing the urban heat and the urban heat island. To sum up, we have found no research that independently attributes the role of water space in reducing heat-related health risks. Only a few articles have drawn attention to the role of the water space along with green space, such as the article entitled "Modification of Heat-Related Mortality in an Elderly Urban Population by Vegetation (Urban Green) and Proximity to Water (Urban Blue): Evidence from Lisbon, Portugal (Burkart et al., 2016)." This article shows that urban green and blue spaces mitigate heat-related mortality in the elderly population in Lisbon. Increasing vegetation may be an excellent strategy to decrease the impact of urban heat. Also, the potential benefits of urban blue spaces may be presented several kilometers away from the blue infrastructure.

To conclude, the research background clarifies some considerable points, including the fact that most studies have focused on green infrastructure, and often blue-green infrastructure has not been considered as an integrated concept. On the other hand, the case study of each of these studies has been conducted in a specific climatic region, which makes it challenging to use the nature-based solutions resulting from them in cities with different climates. Also, most of these case studies are in developed European and American cities, but Middle Eastern cities, especially Iran, have been less researched. However, the results of some recent researches in the Middle East show an increasing trend in heat extremes and intensification of the hot desert climate, projected to accelerate in the future (Lelieveld et al., 2016, 245-46). Moreover, some researches show more temperature rise in this region and its significant consequences on human health in the coming years. Also, in the coming decades, Iran will experience an increase in the average temperature of more than 2.[5] centigrade and more hot days and nights. And these will have considerable consequences on human health and society. Some articles such as "Monitoring and analysis of the effects of atmospheric temperature and heat extreme of the environment on human health in Central Iran, located in southwest Asia" (Kolvir, Madadi, Safarianzengir & Sobhani, 2020) indicate the importance of this issue in Iran. For instance, according to the mentioned paper, the increasing trend of thermal stresses of 15 synoptic stations (1988–2018) and the prevalence of heat-related mortality have been proven in the study area. Therefore, evaluating the role of BGI in reducing temperature and heat-related health risks in Iran is essential. In addition, determining the most effective indicators of BGI in decreasing the temperature in different cities of Iran requires further research. Finally, it is vital to mention that the area and per capita of green-blue infrastructure are investigated in this research, too.

Research questions and hypothesis

This research is based on the hypothesis that Increasing the BGI per capita in different city districts will reduce the temperature and the number of heat-related patients in those areas.This study also seeks to answer these questions What is the relationship between LST and the number of ambulance calls for heat-related disease in the six districts in Qazvin City? What is the relationship between LST and BGI per capita in the six districts? What relationship is between BGI per capita and the percentage of the area of BGI in the six districts and the number of ambulance calls for heat-related diseases (heat stroke, cardiovascular disease, stroke, and respiratory)?

Research method

- **Study area**

The city of Qazvin is located in the central part of Iran (36′16N, 50′00E) with a cold and semi-arid climate, affected by climate change impacts. "Qazvin province has a high potential for greenhouse gas emissions due to its proximity to the capital, locating on the transportation route of several neighboring provinces, having more than fifteen active industrial towns, Shahid Rajaei power plant, and countless mines and resources in operation" (Parhizkari & Mozafari, 2017). The production of more greenhouse gases in the Qazvin province, as the leading cause of climate change, affects Qazvin city as the capital of the province. The most important effects of climate change in this city are the temperature increase and rainfall decrease (Akbari, Najafi Alamdarlo & Moosavi, 2019; Ababaei, Sohrabi & Mirzaei, 2013). Some studies show that this trend (warming continues in the future) (Zehtabian, Salajegheh, Malekian, Boroomand & Azareh, 2016). Also, some other studies predict that the average monthly minimum and maximum daily temperature will increase to about 3°C by 2050 (Ghorbani & Valizadeh, 2014). This trend can have devastating effects on the health of citizens. Therefore, the implementation of suitable strategies in the urban landscape planning to mitigation and adaption to climate change should be given priority in Qazvin, aiming to reduce possible future risks.

- **Data**

- Health statistics

According to the ambulance dispatch data from Qazvin Emergency Medical Center, there are six ambulance dispatchers in the city, and therefore, Emergency Medical Center divides the city into six districts (Razi, Ferdowsi, Minoodar, Molavi, Pardis, and Kowsar). We set the boundaries of these six districts on the BGI map. Besides, heat-related ambulance calls can include Breathing Problems, Cardiac or Respiratory Arrest, Chest Pain, heat Exposure, and Stroke/Cerebrovascular Accident (Graham et al., 2016). Also, among the common diseases caused by climate change in Iran, we can mention stroke, heart attack, respiratory attacks related to air pollution (asthma), and heat stress (DoE, 2010, 128). Therefore, we selected heat-related physical diseases in this study from the four following categories: heat stroke, cardiovascular disease, stroke, and respiratory. Then, we extracted the total number of monthly ambulance calls for each district for these four categories from April 2018 to August 2020. This monitored data have been received from the statistics department of Qazvin Emergency Medical Center, which are shown in the Table 1.

In Table 1, the number of cardiovascular, stroke, and respiratory patients shows that the districts of Molavi and Ferdowsi have the highest number of ambulance calls compared to the Pardis district, with the lowest number. Razi, Minoodar, and Kowsar districts are also located between them. Moreover, in this table, the number of heatstroke calls shows that Molavi and Ferdowsi districts still have the highest number of ambulance calls. Razi and Pardis districts are in the second and third rank, respectively, while no cases have been reported in Kowsar and Minodar's districts.

- Blue-green infrastructure data

We examined the land use map of Qazvin city prepared by Qazvin Municipality in GIS software and recognized the BGI. The green infrastructure includes parks, green plazas, green spaces on boulevards, streets, alleys, ramps and loops, gardens, agricultural areas, and natural reserves marked on the map. Then the water spaces,

Table 1. The annual number of selected heat-related ambulance calls in six districts. Source: Monitored data from the statistics department of Qazvin Emergency Medical Center, 2019.

Ambulance calls for heat stroke					Ambulance calls for cardiovascular disease				
	2018	2019	2020	All years		2018	2019	2020	All years
Razi	1	1	0	2	Razi	427	463	207	1097
Ferdowsi	3	0	0	3	Ferdowsi	759	975	258	1992
Minoodar	0	0	0	0	Minoodar	419	562	191	1172
Molavi	1	1	1	3	Molavi	743	893	278	1914
Pardis	1	0	0	1	Pardis	66	321	169	556
Kowsar	0	0	0	0	Kowsar	536	547	204	1287
Ambulance calls for stroke					Ambulance calls for respiratory disease				
Razi	32	34	26	92	Razi	107	151	65	323
Ferdowsi	63	81	27	171	Ferdowsi	173	246	88	507
Minoodar	31	46	23	100	Minoodar	129	178	61	368
Molavi	80	74	35	189	Molavi	204	270	111	585
Pardis	8	26	16	50	Pardis	16	137	77	230
Kowsar	43	65	18	126	Kowsar	127	151	74	352

including the seasonal rivers and the water canals, are marked on the map. Additionally, two seasonal rivers flow from north to south inside the city. The Barajin river is on the east side, and the Bazaar river is on the west side. Parts of these two rivers are covered, but other parts are in the urban open space where it is possible to reduce the temperature, and people interact with them, which were identified as blue infrastructure. In addition, there are several water canals, the most important of which is the east-west canal in the north of the city, acting as blue infrastructure. However, the covered parts of them are not mentioned. Finally, we mapped the GI with green color, the BI with blue color, and other land uses with wheat color in the map (Fig. 1) to find the location, shape, and distribution of the green-blue infrastructure in the city.

We checked the amount and location of vegetation in the city using the Normalized Vegetation Difference Index (NDVI) map. This index is used to quantify vegetation and helps to understand the density and health of vegetation. This index quantifies vegetation by measuring the difference between red bands (R) and near-infrared (NIR) and is calculated as follows: (NIR - R) / (NIR + R). This formula generates a value between -1 and +1. a high NDVI value (closer to +1) Indicates denser and healthier vegetation and vice versa. This study used Landsat 8 satellite images on 1/01/2021 with the lowest cloud cover percentage (0.13%). We got these images from usgs.gov (U.S. Geological Survey) and calculated the index for Landsat 8 images according to the following formula in GIS software: NDVI = (Band 5 - Band 4) / (Band 5 + Band 4) (USGS, 2021).

The produced map corresponds to the green space map based on the municipal land use map. Therefore, we calculated the area and per capita of green and blue spaces based on the land use map prepared by the municipality. Also, we compared the BGI in this map with the city's satellite image, corrected a few errors for better estimation. After that, we calculated area percentage and GI and BI per capita in each district according to the following method. The per capita availability of GI (BI): area of GI(BI) (sq. m)/population. And area percentage of GI(BI): area of GI(BI)/total area (Table 2).

The data indicate that Molavi district has the lowest area percentage and per capita of BGI, and Ferdowsi district is next rank. On the other hand, Pardisdistrict has the most area percentage and per capita of BGI, and Minoder is next rank.

• Analyzing Surface Urban Heat Island (SUHI)

Measuring surface urban heat islands needs land surface temperature (LST) maps of the city. The

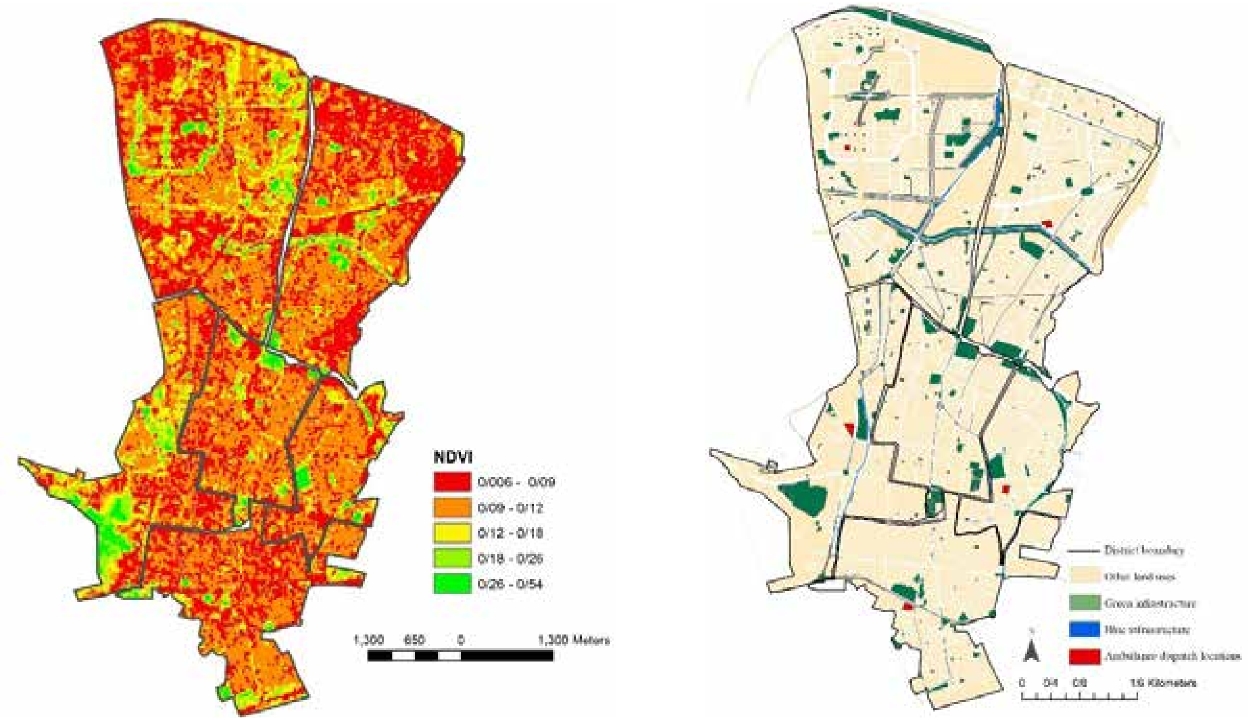

Fig. 1. Right: Location of BGI in Qazvin map. Source: Using the GIS map of Qazvin city prepared by Qazvin Municipality, September 2016, left: NDVI map, February 2017. Source: Authors.

Table 2. Inhabitants, total area, area percentage, and per capita of GI and BI in each district of Qazvin. Source: Authors using GIS map information of Qazvin Municipality, 2020.

Districts	Number of inhabitants	Area (m2)	(GI) area (m2)	(BI) area (m2)	(GI) area (%)	BI area (%)	GI per capita	BI per capita
Razi	81455	4780135	475321	21981	10	0/4	5/9	0/26
Ferdowsi	48720	2433922	261902	7580	10/7	0/3	5/4	0/15
Minoodar	96028	7398520	1015574	82052	13/7	1/1	10/6	0/85
Molavi	69000	3499119	275959	6886	7/8	0/2	4	0/1
Pardis	32162	3982030	398617	57147	10	1/4	12/4	1/8
Kowsar	28096	1851743	210579	0	11/4	0	7/5	0

best way to get the LST is remote sensing methods. Therefore, we used MODIS (The Moderate Resolution Imaging Spectroradiometer) data on the Terra satellites to calculate the LST. Used MODIS data is A2.006_MOD11, stored on a 1-km Sinusoidal grid as the average value of clear-sky LSTs days and nights during 8 days, on a 1 km network at 10: 30 and 22: 30 (Hashemi Darebadami, Darvishi Boloorani, AlaviPanah, Maleki & Bayat, 2019). The data was retrieved, processed, and analyzed on the Google Earth Engine (GEE) platform.

- **Statistical analysis**

In this article, all statistical analyses were produced in SPSS software. First, we conducted a linear correlation analysis with the number of heat-related ambulance calls (dependent variable) and indicators of green-blue infrastructure (independent variable), including total area, area, percentage of the area, and GI and BI per capita. We used Spearman's Rank Correlation Coefficient. This coefficient is from - 1 to + 1 when larger than 0. 7 indicates a strong correlation. Moreover, we calculated the mean and standard deviation of the number of heat-related ambulance calls for six ambulance dispatch locations. After that, we computed multiple comparisons of the mean between every two areas for four diseases, and finally, this paper used the ANOVA test, the one-way analysis of variance, to find any statistically considerable differences between the means of two or more independent groups (Table 6). On the other hand, we mapped health data on the city map and then combined this map with the BGI map by GIS Analise to show how the variables relate.

Results and discussion

• Land surface temperature and disease

Qazvin has only one synoptic meteorological station located in the airport area (southeast of the city). For this reason, the meteorological data of this station can not show air temperature differences in various districts. Therefore, the LST map can be a good reference for spatial distribution surface temperature and hotspots analysis in the regions of Qazvin. In this regard, we produced average LST maps (day and night) during the research period (April 2018 to August 2010). The average LST map of daytime of Qazvin shows, during the morning, negative Urban Heat Island (UHI), what is called the Urban Cold Island effect (UCI). The cause of this phenomenon is the difference in heat capacity at various surfaces. High heat capacity materials in urban areas store solar heat energy during the day, and the temperature of these areas is lower than others. The opposite of this phenomenon occurs at night because the buildings (or other urban elements) still maintain their temperature and have a higher temperature in comparison to others (Hashemi Darebadami et al., 2019). As mentioned above, the average LST map of nighttime and the diagram of UHI profiles of Qazvin city (Figs. 2 & 3) well show the surface urban heat island in the city center. Also, these results are confirmed by the temperature change trend map of the city in ten years (April 2009 to August 2020). The average LST map of nighttime, combined with heat-related ambulance call statistics, indicates a correlation between surface temperature and the number of patients (Fig. 2). In other words, districts with higher surface temperatures (especially Ferdowsi and Molavi's districts) have more heat-related patients.

• Blue-green infrastructure and land surface temperature

As mentioned earlier, both green and blue spaces can be effective in reducing urban heat. If the two are used together, they can increase cooling and effectively mitigate the UHI. Putting together the maps of UHI, temperature change trend, and BGI availability (per capita) ranking, we observed the highest surface temperature in Molavi and Ferdowsi districts with the lowest BGI availability level. During the last ten years, the average temperature in most of these two districts has increased to about 7. 5 degrees Celsius. Conversely, in the Pardis district with the highest BGI availability, not only the surface temperature intensity has decreased, but also

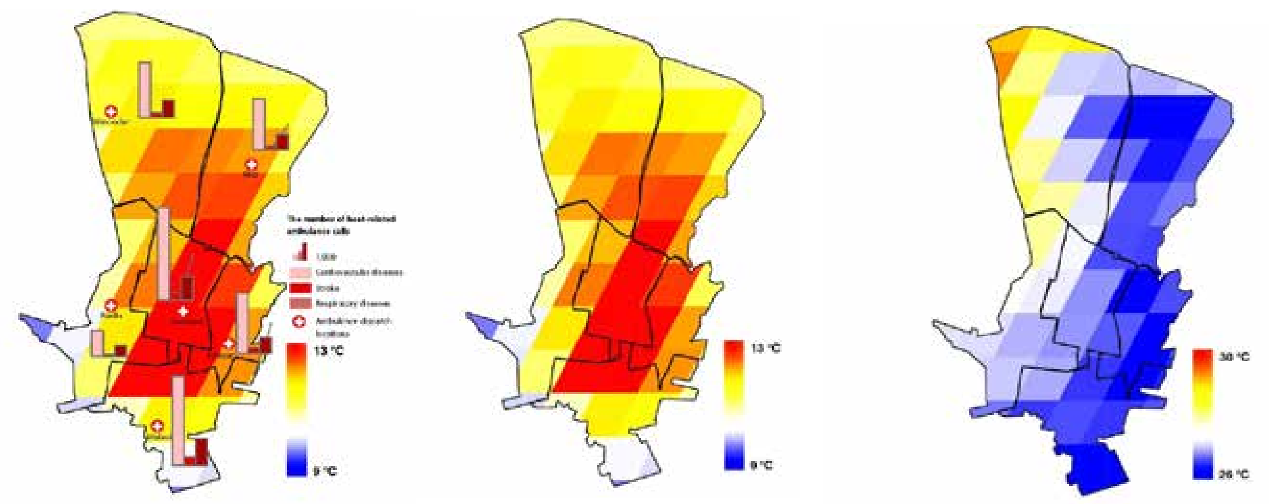

Fig. 2. Right:. Spatial distribution of the daytime average LST map of Qazvin (April 2018 to August 2020), middle. Middle image. Spatial distribution of the nighttime average LST map of Qazvin (April 2018 to August 2020). Left: Daytime average LST map combined with the number of heat-related ambulance calls in six districts. Source: Authors.

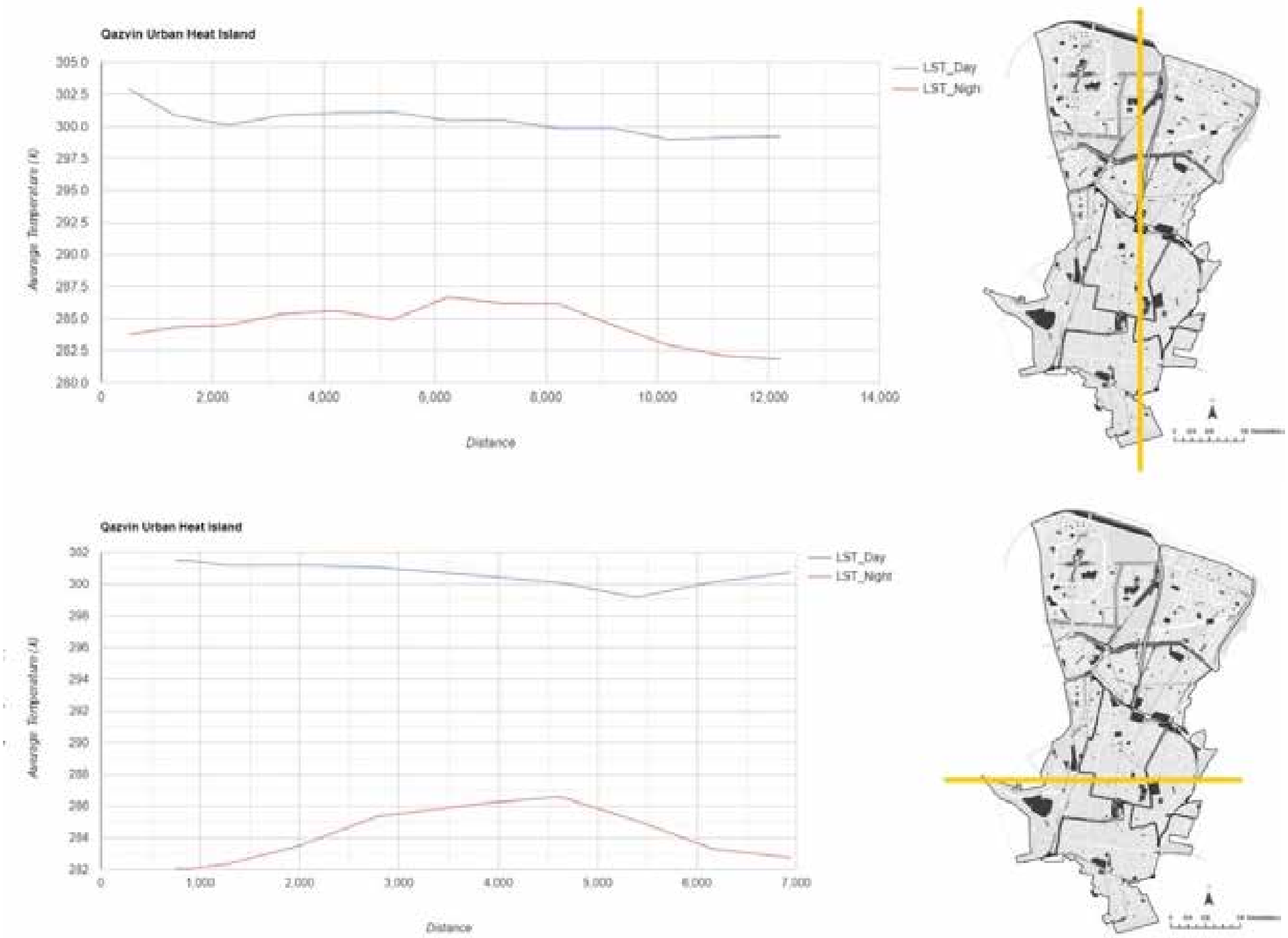

Fig. 3. Surface urban heat island profiles of daytime and nighttime of Qazvin city (April 2018 to August 2020). Source: Authors.

the temperature changes trend in most of this area has dropped (about 4 degrees) (Fig. 4).

- **Blue-green infrastructure and disease**

The correlation between the number of heat-related ambulance calls (dependent variable) and the BGI indicators (independent variable), including area, area percentage, and per capita, is shown in Table 3. The correlation coefficients show that GI per capita has a robust significant inverse relationship with the number of ambulance calls for cardiovascular, stroke, and respiratory diseases. Also, BI per capita has a meaningful inverse relationship with the number of ambulance calls in both cardiovascular disease and stroke. However, other indicators such as the BGI area percentage do not show any meaningful relationship. Ambulance calls for heatstroke have no significant relationship with all BGI indicators, probably due to the few ambulance calls for heatstroke during the selected period.

In the Multiple Comparisons of the mean, the number of heat-related ambulance calls (Table 5) shows strong, significantly different mean values in cardiovascular emergency calls. We ranked districts based on comparisons of the means in Table 5. Molavi, Ferdowsi, Razi, Minoodar, Kowsar, and Pardis districts are ranked one to six. In cases where comparisons of the mean between the two districts did not show a meaningful difference, we compared the standard deviation (Table 4).

We used the same ranking for emergency calls in stroke and, thus, Molavi, Ferdowsi, Kowsar, Minoodar, Razi, and Pardis districts are ranked one to six, respectively. We used the same ranking for emergency calls in stroke and, Molavi, Ferdowsi, Kowsar, Minoodar, Razi, and Pardis districts were ranked one to six, respectively. Also, Molavi, Ferdowsi, Minoodar, Kowsar, Razi, and Pardis districts were ranked one to six in respiratory

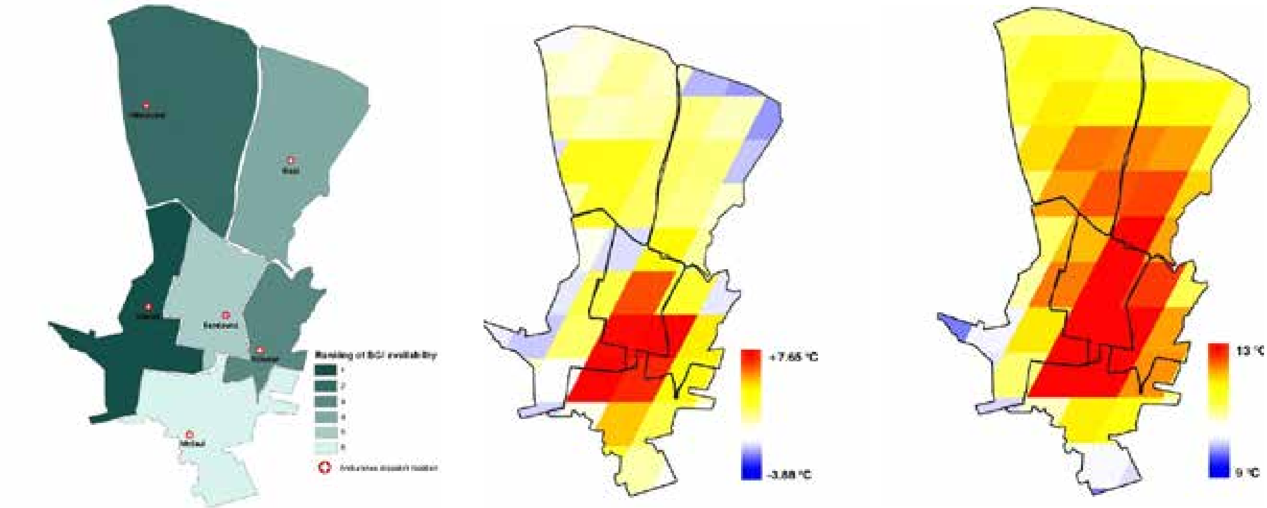

Fig. 4. Right: Spatial distribution of the nighttime average LST map of Qazvin city (April 2018 to August 2020). middle. The temperature change trend map during a ten-year period (April 2009 to August 2020). Left: BGI availability ranking map in six districts. Source: Authors.

Table 3. Spearman correlation between BGI indicators and the number of heat-related ambulance calls. Source: Authors.

		The number of heat-related ambulance calls			
BGI indicators		Heatstroke	Cardiovascular	Stroke	Respiratory
Total area	r1	-0.357	-0.364	-0.421	-0.253
	P-value2	0.488	0.478	0.405	0.628
(GI) area	r	-0.331	-0.336	-0.405	-0.272
	P-value	0.522	0.515	0.426	0.602
(BI) area	r	-0.432	-0.610	-0.657	-0.512
	P-value	0.392	0.198	0.156	0.299
(GI) area (%)	r	-0.149	-0.284	-0.370	-0.396
	P-value	0.777	0.585	0.470	0.437
(BI) area (%)	r	-0.354	-0.706	-0.742	-0.601
	P-value	0.491	0.117	0.091**3	0.207
(GI) per capita	r	-0.538	-0.838	-0.842	-0.798
	P-value	0.271	0.037*4	0.035*	0.057*
(BI) per capita	r	-0.396	-0.775	-0.779	-0.670
	P-value	0.436	0.070**	0.068**	0.145

emergency calls, respectively. Thus, in cardiovascular diseases, stroke, and respiratory, Molavi and Ferdowsi's districts have the highest number, while the Pardis district has the lowest number of patients.
Moreover, in heatstroke calls, only the Ferdowsi district has a significant mean difference with the other three districts of Minoodar, Pardis, and Kowsar and has a higher mean than them, and there is no significant mean difference between Molavi and Razi's districts. But as mentioned, due to the few calls, these results can not be completely reliable.

In addition, we put both layers of GI per capita and BI per capita (separately) on the layer of the number of patients (cardiovascular, stroke, and respiratory) in six districts using GIS. with this work, we could generate concept maps and display statistical analyzes graphically (Fig. 5).
Separately, we combined heat stroke statistics with the amount of BGI per capita on the city map because the few numbers of that were not comparable to the statistics of the other three diseases. The generated map shows an inverse correlation between the

Table 4. Mean and std. Deviation of the number of heat-related ambulance calls. Source: Authors.

Heat-related disease	Districts	Mean	Std. Deviation	Heat-related disease	Districts	Mean	Std. Deviation
Heatstroke	Razi	0.0690	0.25788	Stroke	Razi	3.1724	2.26887
	Ferdowsi	0.2069	0.55929		Ferdowsi	5.8966	2.02387
	Minoodar	<0.0001	<0.0001		Minoodar	3.4483	2.09738
	Molavi	0.0345	0.18570		Molavi	6.5172	2.65412
	Pardis	<0.0001	<0.0001		Pardis	1.7241	1.68812
	Kowsar	<0.0001	<0.0001		Kowsar	4.3448	2.04024
Cardiovascular	Razi	37.8276	8.10674	Respiratory	Razi	11.1379	6.02213
	Ferdowsi	68.6897	18.75996		Ferdowsi	17.4828	10.66242
	Minoodar	40.4138	9.32936		Minoodar	12.6897	6.93389
	Molavi	66.0000	14.70666		Molavi	20.1724	7.68611
	Pardis	19.1724	14.10185		Pardis	7.9310	7.73642
	Kowsar	44.3793	10.91007		Kowsar	12.1379	7.20478

number of heatstroke patients and the BGI per capita (Fig. 6).

Summarizing the results demonstrates that Molavi district with the lowest BGI per capita has the most ambulance calls in all three cardiovascular diseases, stroke and respiratory, and has a significant mean difference with other regions. Ferdowsi district is in the next rank after Molavi in the three mentioned diseases because it has the lowest per capita of BGI after Molavi. Also, the Pardis district with the most BGI per capita has the minimum ambulance calls for all three diseases. In addition, Ferdowsi and Molavi districts with minimum BGI availability have the highest rank of ambulance calls of heatstroke, and the Razi district is next. Briefly, a strong significant inverse relationship between BGI availability (per capita) and the number of Ambulance calls in four diseases (Fig. 7).

Conclusion

One of the contributing factors in the cooling of BGI in the city is size, which has two leading indicators; Percentage of the area and per capita. The per capita indicator depends on the amount and distribution of BGI and population in the city. However, the percentage of the area only refers to the amount of BGI proportion to the total area. Our main goal in this study was to compare the effect of these two indicators on heat-related morbidity in Qazvin to determine which one is more effective. The statistical analysis results and the combination of health and BGI data in Qazvin illustrate that the amount of BGI availability can reduce heat-related health risks. Besides, the size and distribution of BGI in proportion to the population is more effective in reducing the temperature and heat-related morbidity than the percentage of area. In other words, increasing the amount of BGI availability in any urban region by decreasing the temperature can mitigate the number of heat-related patients. Conversely, reducing the amount of BGI availability (particularly GI) will increase the temperature and be a threat to the health of citizens. As a result, these findings confirm the research hypothesis. To answer the first and second research questions, we pointed to the link between three main factors: temperature (surface urban heat island), heat-related morbidity (cardiovascular, stroke, respiratory, and heat stroke), and BGI per capita. These factors have meaningful pairwise correlations in all six districts. Also, temperature, as a mediator variable, explains the type of relationship between an independent variable (BGI) and its dependent variable (disease). In this research, the independent variable cannot directly influence the dependent variable; instead, it utilizes a third variable. Thus, decreasing the amount of BGI availability

Table 5. Multiple comparisons of the mean numbers of the r heat-related ambulance calls. Source: Authors.

Heat-related disease	(I) District	(J) District	Mean Difference (I-J)	p-values	Rank	Heat-related disease	(I) District	(J) District	Mean Difference (I-J)	p-values	Rank
Heatstroke	Razi	Ferdowsi	-0.13793	0.347	2	Cardiovascular	Razi	Ferdowsi	-30.86207	<0.0001*	3
		Minoodar	0.06897	0.917				Minoodar	-2.58621	0.975	
		Molavi	0.03448	0.996				Molavi	-28.17241	<0.0001*	
		Pardis	0.06897	0.917				Pardis	18.65517	<0.0001*	
		Kowsar	0.06897	0.917				Kowsar	-6.55172	0.408	
	Ferdowsi	Razi	0.13793	0.347	1		Ferdowsi	Razi	30.86207	<0.0001*	2
		Minoodar	0.20690	0.036*				Minoodar	28.27586	<0.0001*	
		Molavi	0.17241	0.130				Molavi	2.68966	0.971	
		Pardis	0.20690	0.036*				Pardis	49.51724	<0.0001*	
		Kowsar	0.20690	0.036*				Kowsar	24.31034	<0.0001*	
	Minoodar	Razi	-0.06897	0.917	3		Minoodar	Razi	2.58621	0.975	4
		Ferdowsi	-0.20690	0.036*				Ferdowsi	-28.27586	<0.0001*	
		Molavi	-0.03448	0.996				Molavi	-25.58621	<0.0001*	
		Pardis	<0.0001	1.000				Pardis	21.24138	<0.0001*	
		Kowsar	<0.0001	1.000				Kowsar	-3.96552	0.861	
	Mowlavi	Razi	-0.03448	0.996	2		Mowlavi	Razi	28.17241	<0.0001*	1
		Ferdowsi	-0.17241	0.130				Ferdowsi	-2.68966	0.971	
		Minoodar	0.03448	0.996				Minoodar	25.58621	<0.0001*	
		Pardis	0.03448	0.996				Pardis	46.82759	<0.0001*	
		Kowsar	0.03448	0.996				Kowsar	21.62069	<0.0001*	
	Pardis	Razi	-0.06897	0.917	3		Pardis	Razi	-18.65517	<0.0001*	6
		Ferdowsi	-0.20690	0.036*				Ferdowsi	-49.51724	<0.0001*	
		Minoodar	<0.0001	1.000				Minoodar	-21.24138	<0.0001*	
		Molavi	-0.03448	0.996				Molavi	-46.82759	<0.0001*	
		Kowsar	<0.0001	1.000				Kowsar	-25.20690	<0.0001*	
	Kowsar	Razi	-0.06897	0.917	3		Kowsar	Razi	6.55172	0.408	5
		Ferdowsi	-0.20690	0.036*				Ferdowsi	-24.31034	<0.0001*	
		Minoodar	<0.0001	1.000				Minoodar	3.96552	0.861	
		Molavi	-0.03448	0.996				Molavi	-21.62069	<0.0001*	
		Pardis	<0.0001	1.000				Pardis	25.20690	<0.0001*	

in each district will lead to increase temperature and, consequently, growth in the number of heat-related patients in that district and vice versa. In response to the third question, we investigated the relationship between the two BGI indicators (per capita and percentage of area) with four categories of heat-related morbidity. The results showed a strong significant correlation between GI per capita and the number of ambulance calls for cardiovascular, stroke, and respiratory diseases. There was also a meaningful correlation between per capita of BI and the number of ambulance calls for cardiovascular disease and stroke. Such correlations are not valid for the percentage of the area of BI and GI.

Therefore, the per capita index is more effective than the percentage of area. In other words, greater population access to green-blue infrastructure in any urban area reduces heat-related health risks in that area. Inhabitants in any urban region with more

Rest of Table 5.

Heat-related disease	(I) District	(J) District	Mean Difference (I-J)	p-values	Rank	Heat-related disease	(I) District	(J) District	Mean Difference (I-J)	p-values	Rank
Stroke	Razi	Ferdowsi	-2.72414	<0.0001*	5	Respiratory	Razi	Ferdowsi	-6.34483	0.029*	5
		Minoodar	-0.27586	0.997				Minoodar	-1.55172	0.975	
		Molavi	-3.34483	<0.0001*				Molavi	-9.03448	<0.0001*	
		Pardis	1.44828	0.111				Pardis	3.20690	0.628	
		Kowsar	-1.17241	0.304				Kowsar	-1.00000	0.997	
	Ferdowsi	Razi	2.72414	<0.0001*	2		Ferdowsi	Razi	6.34483	0.029*	2
		Minoodar	2.44828	<0.0001*				Minoodar	4.79310	0.189	
		Molavi	-0.62069	0.881				Molavi	-2.68966	0.781	
		Pardis	4.17241	<0.0001*				Pardis	9.55172	<0.0001*	
		Kowsar	1.55172	0.071				Kowsar	5.34483	0.104	
	Minoodar	Razi	0.27586	0.997	4		Minoodar	Razi	1.55172	0.975	3
		Ferdowsi	-2.44828	<0.0001*				Ferdowsi	-4.79310	0.189	
		Molavi	-3.06897	<0.0001*				Molavi	-7.48276	0.005*	
		Pardis	1.72414	0.031*				Pardis	4.75862	0.195	
		Kowsar	-0.89655	0.607				Kowsar	0.55172	1.000	
	Mowlavi	Razi	3.34483	<0.0001*	1		Mowlavi	Razi	9.03448	<0.0001*	1
		Ferdowsi	0.62069	0.881				Ferdowsi	2.68966	0.781	
		Minoodar	3.06897	<0.0001*				Minoodar	7.48276	0.005*	
		Pardis	4.79310	<0.0001*				Pardis	12.24138	<0.0001*	
		Kowsar	2.17241	0.002*				Kowsar	8.03448	0.002*	
	Pardis	Razi	-1.44828	0.111	6		Pardis	Razi	-3.20690	0.628	6
		Ferdowsi	-4.17241	<0.0001*				Ferdowsi	-9.55172	<0.0001*	
		Minoodar	-1.72414	0.031*				Minoodar	-4.75862	0.195	
		Molavi	-4.79310	<0.0001*				Molavi	-12.24138	<0.0001*	
		Kowsar	-2.62069	<0.0001*				Kowsar	-4.20690	0.323	
	Kowsar	Razi	1.17241	0.304	3		Kowsar	Razi	1.00000	0.997	4
		Ferdowsi	-1.55172	0.071				Ferdowsi	-5.34483	0.104	
		Minoodar	0.89655	0.607				Minoodar	-0.55172	1.000	
		Molavi	-2.17241	0.002*				Molavi	-8.03448	0.002*	
		Pardis	2.62069	<0.0001*				Pardis	4.20690	0.323	

available to BGI are less likely to experience heat-related morbidity. For this reason, we recommend that the city decision-maker prioritize the most densely populated districts in Qazvin city as critical points in urban landscape planning to mitigate the consequences of climate change. Thus, the urban landscape management of adequately locating the new BIG or maintaining the existing infrastructure will increase the level of health and result in health justice. Therefore, the results of this research can impact better urban landscape planning and design in the future. Another point is that cardiovascular disease is more important among the four mentioned diseases. This disease, along with respiratory diseases and stroke, is known as a heat-related illness and has a significant inverse relationship with BGI per capita. Also, the most important cause of death is in Iran. Therefore, it is appropriate to pay special attention to increasing the BGI per capita t in the country to help reduce cardiovascular disease and improve the human lifespan.

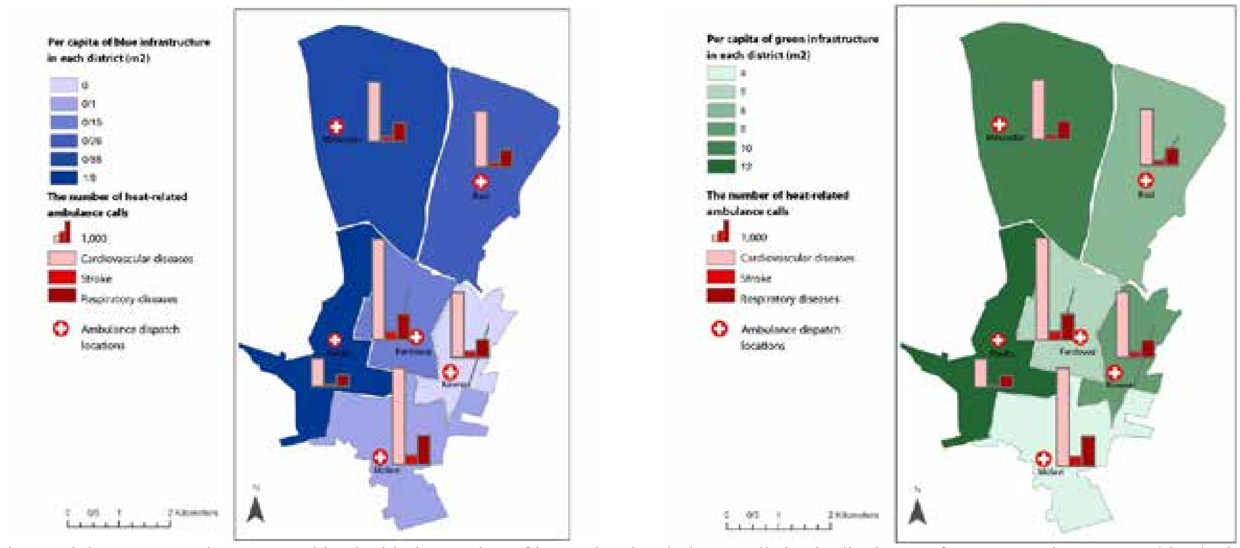

Fig. 5. Right: GI per capita map combined with the number of heat-related ambulance calls in six districts. Left: BI per capita map combined with the number of heat-related ambulance calls in six districts. Source: Authors.

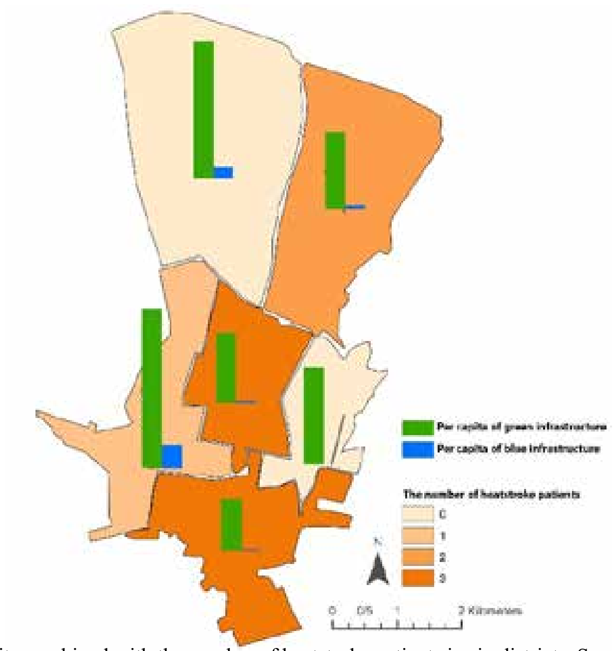

Fig. 6. The amount of GI and BI per capita combined with the number of heatstroke patients in six districts. Source: Authors.

Endnote

1. Correlation coefficient
2. Meaningful
3. ** p < 0.1 Medium significant correlation in bold
4. * p < 0.5, Significant correlations in bold

Reference list

• Ababaei, B., Sohrabi, T. M. & Mirzaei, F. (2013). Climate change scenarios in Qazvin irrigation and drainage network. *Water Engineering*, 5(15), 31-55..

• Akbari, M., Najafi Alamdarlo, H. & Moosavi, S. h. (2019). Impacts of Climate Change and Drought on Income Risk and Crop Pattern in Qazvin Plain Irrigation Network. *Journal of Water Research in Agriculture,* 33, (2), 265-281.

• Antoszewski, P., Świerk, D. & Krzyżaniak, M. (2020). Statistical Review of Quality Parameters of Blue-Green Infrastructure Elements Important in Mitigating the Effect of the Urban Heat Island in the Temperate Climate (C) Zone. *International journal of environmental research and public health,* 17, 7093.

• Benedict, M. A. & T McMahon, E. (2002). Green infrastructure: smart conservation for the 21st century. *Renewable Resources Journal*, 20, 12-17.

• Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P.,… Endlicher, W. (2016). 'Modification of heat-related mortality in an elderly urban population by vegetation (urban green)

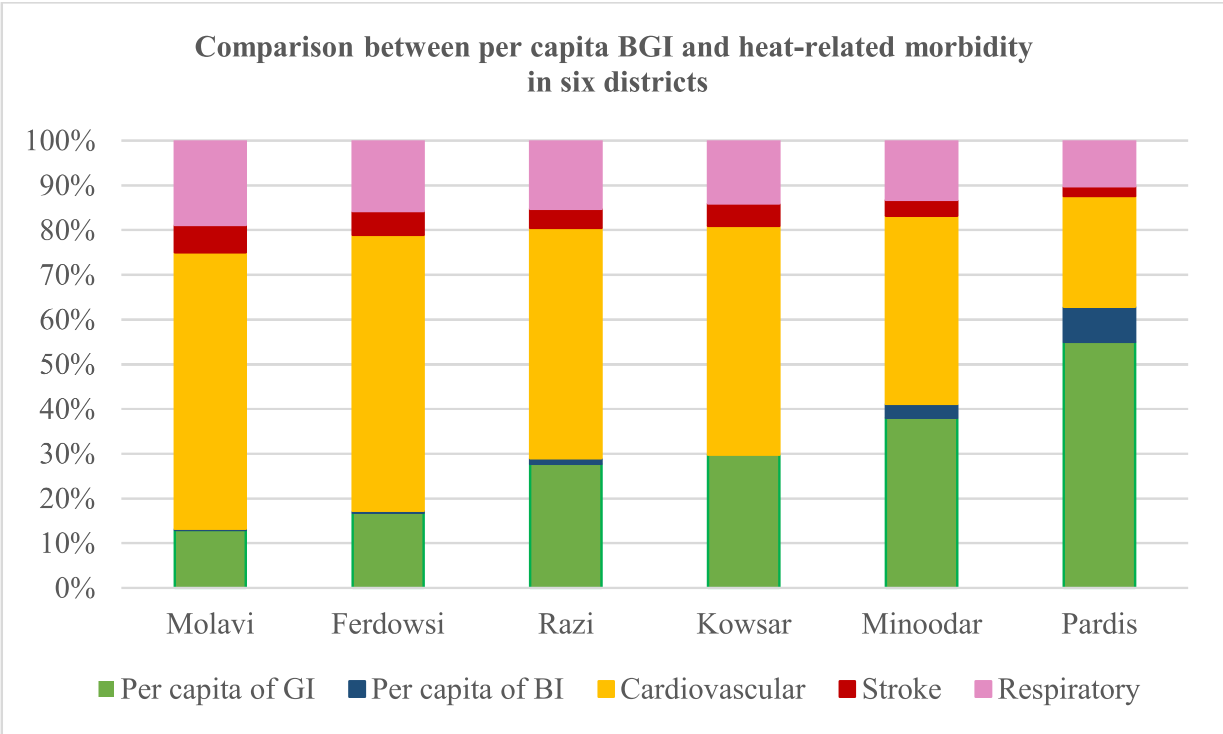

Fig. 7. Diagram of comparison between BGI per capita and heat-related morbidity in six districts. Source: Authors.

and proximity to water (urban blue): evidence from Lisbon, Portugal' *Environmental Health Perspectives*, 124, 927-934.

• DoE, UNDP. (2010). *Iran's Second National Communication to UNFCCC.* Department of Environment, United Nations Development Programme. http://unfccc.int/ resource/docs/natc/ iranc2.pdf.

• Faggian, R. & Sposito, V.A. (2009). *Systemic regional developement-a systems thinking approach.* In Proceedings of the 53rd Annual Meeting of the ISSS-2009, Brisbane, Australia.

• Faggian, R., Romeijin, H. & Sposito, V. (2012). *Soil data to support broad scale land suitability assessment in the Gippsland Region*. Melbourne: Agricultural Victoria Services.

• Gehrels, H., Van der Meulen, S., Schasfoort, F., Bosch, P., Brolsma, R., Van Dinther, D., … & Kok, S. (2016). *Designing green and blue infrastructure to support healthy urban living.* Retrieved Feb 14, 2021, from https://publicaties.ecn.nl/PdfFetch.aspx?nr=ECN-O--16-029.

• Ghorbani, K. & Valizadeh, E. (2014). Validating Of SSIIM 3D Model For Flow Field Simulation In a U Shape Channel Bend With Intake. *Journal of Water and Soil Conservation*, 21(4), 197-214.

• Gill, S. E, Handley, J.F., Ennos, A.R. & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33, 115-33.

• Graham, D. A., Vanos, J.K., Kenny, N.K. & Brown, R.D. (2016). The relationship between neighbourhood tree canopy cover and heat-related ambulance calls during extreme heat events in Toronto, Canada. *Urban Forestry & Urban Greening,* 20, 180-86.

• Graham, D. A., Vanos, J.K., Kenny, N.K. & Brown, R.D. (2017). Modeling the effects of urban design on emergency medical response calls during extreme heat events in Toronto, Canada. *International Journal of Environmental Research and Public Health,* 14, 778.

• Hashemi Darebadami, S., Darvishi Boloorani, A., AlaviPanah, S. K., maleki, M. & Bayat, R. (2019). Investigation of changes in surface urban heat-island (SUHI) in day and night using multi-temporal MODIS sensor data products (Case Study: Tehran metropolitan). *Journal of Applied Researches in Geographical Sciences*, 19(52), 113-128.

• Kabisch, N., Korn, H., Stadler, J. & Bonn, A. (2017). *Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice* Switzerland: Springer.

• Kazmierczak, A. & Carter, J. (2010). *Adaptation to climate change using green and blue infrastructure. A database of case studies*. Manchestre: The University of Manchester.

• Kolvir, H.R., Madadi, A., Safarianzengir, V. & Sobhani, B. (2020). Monitoring and analysis of the effects of atmospheric temperature and heat extreme of the environment on human health in Central Iran, located in southwest Asia. *Air Quality, Atmosphere & Health*, 13, 1179-1191.

• Lelieveld, J., Proestos, Y., Hadjinicolaou, P., Tanarhte, M., Tyrlis, E. & Zittis, G. (2016). Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. *Climatic Change*, 137, 245-260.

• Lim, B., Spanger-Siegfried, E., Burton, I., Malone, E. & Huq, S. (2005). *Adaptation policy frameworks for climate change: developing strategies, policies and measures*. Cambridge: Cambridge University Press.

• Liu, B., Lian, Z. & Brown, R.D. (2019). Effect of landscape microclimates on thermal comfort and physiological wellbeing. *Sustainability*, 11, 5387.

• Martinez, G.S., de'Donato, F. & Kendrovski, V. (Eds.) (2021). *Heat and health in the WHO European Region: updated evidence for effective prevention*. Retrieved Apr. 1, 2021, from https://www.euro.who.int/en/health-topics/environment-and-health/Climate-change/publications/2021/heat-and-health-in-the-who-european-region-updated-evidence-for-effective-prevention-2021.

• Mell, I. C. (2008). Green infrastructure: concepts and planning. *FORUM Ejournal*, 69-80.

• Murray, V. & Ebi, K.L. (2012). IPCC special report on managing the risks of extreme events and disasters to advance climate change adaptation (SREX). *Journal of Epidemiology Community Health*. 66, 759-760.

• Parhizkari, A., & Mozafari, M. M. (2017). Assessment the Effects of Greenhouse Gases Emission and Climate Change on Supply and Demand of Irrigation Water and Agricultural Products in Watersheds of Qazvin Province. *Journal of Watershed Management Research*, 7(14), 141-151.

• Patz, J. A., Campbell-Lendrum, D., Holloway, T. & Foley, J.A. (2005). Impact of regional climate change on human health. *Nature*, 438, 310-317.

• Smit, B., Burton, I ,.Klein ,R.J.T & Wandel ,J .(2000) .An anatomy of adaptation to climate change and variability .*Societal Adaptation to Climate Variability and Change* 45, 221-251.

• Tol, R. S. J, Fankhauser, S. & Smith, J.B. (1998). The scope for adaptation to climate change: what can we learn from the impact literature? *Global Environmental Change*, 8, 109-23.

• USGS. (2021). *Landsat Normalized Difference Vegetation Index*. U.S. Geological Survey. https://www.usgs.gov/core-science-systems/nli/landsat/landsat-normalized-difference-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con.

• Venter, Z. S., Krog, N.H. & Barton, D.N. (2020). Linking green infrastructure to urban heat and human health risk mitigation in Oslo, Norway. *Science of The Total Environment*, 709, 136193.

• Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Beagley, J., Belesova, K., … Campbell-Lendrum, D. (2021). The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *The Lancet*, 397(10269), 129-170.

• WHO (World Health Organization). (2019). *Healthy environments for healthier populations: Why do they matter, and what can we do*? Geneva: World Health Organization. Retrieved Apr. 20, 2021, from https://apps.who.int/iris/bitstream/handle/10665/325877/WHO-CED-PHE-DO-19.01-eng.pdf

• Yu, Z., Yang, G., Zuo, Sh., Jørgensen, G., Koga, M. & Vejre, H. (2020). Critical review on the cooling effect of urban blue-green space: A threshold-size perspective. *Urban Forestry & Urban Greening*, 49, 126630.

• Zehtabian, Gh.R., Salajegheh, A., Malekian, A., Boroomand, N. & Azareh, A. (2016). 'Evaluation and comparison of performance of SDSM and CLIMGEN models in simulation of climatic variables in Qazvin plain. *Desert*, 21, 155-164.

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