

Analyzing Existing Urban Green Infrastructure to Face Climate Change Effects in Neighbourhoods: Case study – Yousef Abad Quarter of Tehran

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Abstract: Urban development and climate change are closely related. The concepts of resilience and urban ecological resilience have been proposed to mitigate and adapt to these negative impacts. In this research, urban ecological resilience, and especially, climate resilience, are considered.

Urban green infrastructure has been shown to be effective in reducing the effects of climate change in cities and enhancing the climate resilience. One of the greatest impacts of climate change can be found in cities, and especially, in neighbourhoods. It is necessary to provide solutions in the neighbourhood scale for dealing with the climate change.

This research attempts to answer the general question of: how to achieve a climate resilient neighbourhood, by studying and analyzing the existing urban green infrastructure. The overall objectives of this research include the investigation of the impact of quality, quantity and location of urban green infrastructure and their effect on climate resilience in neighbourhoods, finding and expanding the intervention principles, finding the strategies of adaptation to climate change in relation to green infrastructure and their impact on urban climate resilience and development of the ‘climate’ aspect of resilience through green infrastructure in the neighbourhood scale.

A qualitative-quantitative method was used here on Yousef Abad neighbourhood of Tehran, in Iran. Base and analytical maps were produced with GIS based on aerial photos and the data gathered from field survey. Finally a method of intervening in existing UGI to improve climate resilient in neighbourhoods, was defined in dry areas.

Keywords: Urban green infrastructures; Urban climate resilience; Climate change; Neighbourhood scale; Yousef Abad quarter in Tehran, Iran.

Introduction

Natural disasters are considered a major challenge in the developing countries, which not only cause casualties and emotional suffering for the survivors, but also seriously damage the local economies facing the disaster and thwart the development achievements (Asian Development Bank, 2014).

Cities are exposed to the risk of climate change and are very vulnerable (Mishra, 2017). Cities should

be resistant to a wide range of shocks and pressures, including climate change (Leichenko, 2011). Therefore scholars and planners try to reduce the damages of natural disasters based on different approaches and patterns through the development of appropriate plans. One of these approaches is to investigate the resilience to natural disasters. Today, most natural disasters occur due to climate change. Climate change is a globally widespread phenomenon that is happening in the whole planet (Childers, 2015) and has created serious problems

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for humans and the environment. Resilience is a new concept that is mostly used when facing the unknowns and uncertainties such as climate change (Adhern, 2011). Resilience means that the urban system is able to withstand severe natural disasters without suffering from casualties, damages or loss of production capacity or quality of life (IPCC, 2007). The resilience regarding climate change reduction and adaptation is addressed in this study.

Among the resilience types, what is considered in this research is climate resilience that is a type of urban ecological resilience. ‘Climate resilience’ is the urban resilience to climate change (Carter et al., 2015). In this respect, the review of existing literature shows that few studies so far have addressed the concept of climate resilience, and most studies in the world and Iran, have only focused on the urban resilience and its assessment on the urban and regional scale. A very limited number of studies have addressed the resilience to climate change on other scales, especially the neighbourhood scale.

As a building block of cities, neighbourhood is of great importance, and a resilient city can be achieved by a resilient neighbourhood. On the other hand, one of the important factors influencing the climate resilience is urban infrastructure, especially green infrastructure. However, the main question and objective of this research is how to achieve a methodology or principles to examine current situation of the infrastructure in cities to improve and ensure the climate resilience in the neighbourhood by improving such situations.

To answer the questions of this research, by selecting a case study and the GIS software, data about the status of vegetation and green infrastructure was gathered and data based on the characteristics of green infrastructure’s resilience potentials was analyzed. Also by providing the base and analytical maps, it was attempted to propose and develop a method for interfering with the quantity, quality and location of green infrastructure to increase climate resilience.

Terminology

According to the aforementioned issues, the brief review of the literature and necessary definitions are presented for advancing the research in the methodology section.

Climate Resilience in Neighbourhood Scale

Climate resilience includes the capacity of an independent unit or a group or organization to respond to climate change in a dynamic and effective manner,

while still continuing to daily activities in an acceptable level. This feature includes the resistance to change, recovery after the shock, and reorganization to prevent the destruction of the system, that is the city (Dayland and Brown, 2012). In general, “climate resilience” is the urban resilience to climate change. Various literature has classified the climate resilience as a subcategory of urban ecological resilience (Figure 1).

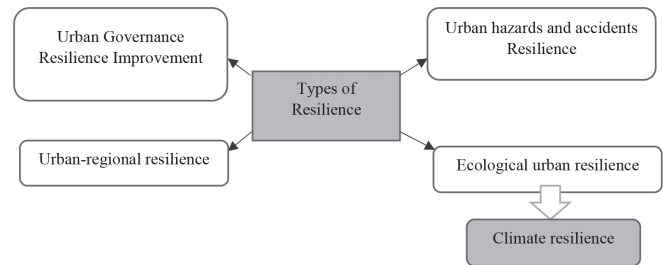


Figure 1: The relationship between climate resilience and resilience types (Shirgir et al., 2019).

The studies conducted by Miller et al. (2009) emphasized the importance of urban infrastructure as an effective factor in creating climate resilience. However, the importance of green urban infrastructure is also considered, which is further discussed here.

The climate resilience on the neighbourhood scale includes the ability of the neighbourhood in the physical-infrastructural, social, political and economic systems and the resistance and efficiency of settlements and buildings to tolerate the hazards of climate change to quickly return to previous situation under these tensions and pressures, and to embrace and confront future threats. One of the greatest impacts of climate change can be found in cities, and especially in neighbourhoods. As one of the most important urban segments, neighbourhoods are no exception to these adverse effects. As a result, it is necessary to provide solutions on neighbourhood scale for dealing with the climate change (Sasanpour et al., 2015).

A resilient neighbourhood is the one that can withstand the shocks and impacts of a change, so that those risks could not turn into a crisis, and also the ability or capacity to return to the previous state during and after the crisis should be institutionalised to make it possible to change and adapt after the crisis. The institutionalisation of resilience in the neighbourhood during the pre-disaster stage reduces vulnerability, avoids and mitigates losses, and leads to the continued ideal conditions of the local community, as far as possible, during the drastic changes, and then, after the changes, to rehabilitate the effects of climate change

(Moxham et al., 2013). In general, it can be stated that resilient neighbourhoods give rise to resilient cities. Among the factors affecting climate resilience and urban resilience is green infrastructures. So far, based on existing literature, the importance of urban infrastructure, including urban green infrastructure, in urban resilience was demonstrated, and it is further addressed in the sequel.

Urban Green Infrastructure in Neighbourhood

Urban green infrastructure (UGI) is a type of ecological social system that results from the interactions of various elements, especially humans. Components of green urban infrastructure (UGI) can be considered a combination of open and closed spaces and a mixture of natural plant habitats, which are of great ecologic, social and economic significance. As a result, the proper design in these spaces can have a profound effect on the everyday life, and the resilient design is considered one of the most appropriate principles for the design of such spaces (Oliver, 2014). In general, green infrastructure includes green roofs, permeable green surfaces, green paths and streets, urban forests, public parks, neighbourhood gardens, and urban wetlands (Demuzere et al., 2014).

For adaptation to climate change, UGI is one of the most important “strategies for adaptation to climate change”. It can bolster the cities and reduce the impacts of climate change in the future (Foster et al., 2011). It certainly reduces the effects of heat islands in cities and the floods (Byrne et al., 2015). To create climate resilience in cities and reduce pollution, there are several solutions, one of which is the planning and design of green spaces. Various studies have explored the importance of urban green infrastructure in balancing water flows and providing the thermal comfort. It is also known to reduce climate change, for example, for controlling flood flows, creating shading, reducing air temperatures, etc. Figure 2 illustrates the role of green infrastructure in the reduction and adaptation to climate change (Demuzere et al., 2014).

On the neighbourhood scale, urban green infrastructure has four important functions related to the establishment and improvement of climate resilience (Sheate et al., 2015), which are shown in Figure 2.

Strategies for Adaptation to Climate Change and Improvement of Climatic Resilience Using Urban Green Infrastructure

According to the conducted studies, three strategic principles were derived for studying and improving

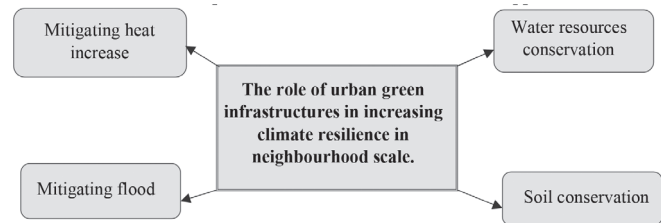


Figure 2: UGI role on increasing climate resilience in neighbourhood scale (Sheate et al., 2015).

existing and proposed green urban infrastructure: 1. Maintaining and enhancing existing vegetation, 2. Using resistant plants to climate change, and 3. Using “landscape ecology” for finding proper locations of vegetation in new urban projects (Gill, 2007):

1. One of the important strategies for reducing the temperature in warm seasons is the identification and maintenance of existing vegetation, whether in private gardens or in public green spaces or green spaces on the streets. However, in many urban areas, there are hard and grey infrastructures, and it is impossible to change the use and replace them with large green spaces. In such conditions, vegetation should be added to the environment with creativity and the use of specific methods. One of these methods is to use green roofs and green facades, plant rows of trees along the streets and railroads, and convert streets into green paths.
2. Another strategy is to use plants resistant to climatic conditions, for example, resistant to drought and water shortage. Of course, drought is one of the negative effects of climate change. Under such conditions, it is effective to use the plants with lower water demand and less susceptibility to climate conditions. Some types of plants are very resistant to specific climatic conditions, including drought. The use of trees in such situations is very suitable. These plants continue to shade and evaporate under severe climatic conditions.
3. To deal with climate change, the location and arrangement of the vegetation is very important. According to Forman and Godron (1986), green infrastructure can be classified into three categories: patch, corridor and matrix. Each of these forms has the following benefits: Corridors are effective in storing the water from flood and controlling flood flow, patches are mostly effective in storing rainwater while the river flooding, the cooling of space through evaporation is further done by patches than matrices, and the appropriate micro-climates are also created in the patches. Matrixes

are more effective in treating the rainwater than the patches. When the green spaces are greater than one hectare, they create a good microclimate. Shading occurs in the patches and matrixes, which leads to cooling of residential areas (Forman, 1995). Generally, green space is effective in reducing the rate and amount of surface runoff in sandy soils. The creation of protected areas on such soils can be a good strategy for the areas with such soil types (Gill, 2007).

Concluding the issues raised in the theoretical section, after introducing the strategies of adaptation to climate change and enhancing the climate resilience using the city-scale urban green infrastructure, a conceptual framework of ‘intervention approaches’ was finally extracted for the green infrastructure to enhance the climate resilience on the neighbourhood scale. These approaches pave the way for this study to answer its main question, “How to develop a method for exploring and improving urban green infrastructure to achieve and enhance the climate resilience on the neighbourhood scale?” In the research method, these approaches are further elaborated and the basic and analytical studies are performed using these approaches in the case study, Yousef Abad neighbourhood of Tehran. Finally, a method will be developed for intervening in such infrastructure on the desired scale which can be extended to other Iranian cities with similar climate conditions. The result of this section is shown in Figure 3.

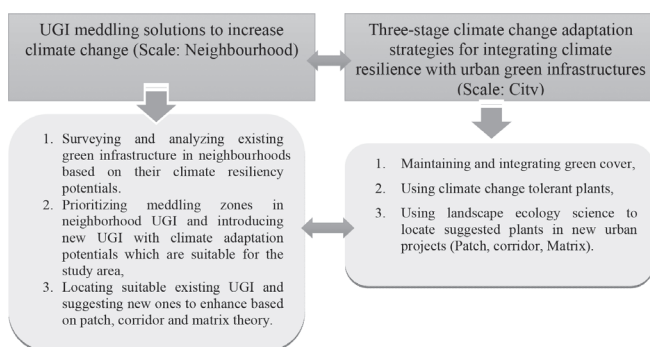


Figure 3: UGI meddling solutions framework to enhance climate resilience in neighbourhood scale based on climate change adaptation strategies in city scale (Shirgir et al., 2019; Gill et al., 2007; Norton et al., 2015).

Research Method

This research uses a qualitative-quantitative approach, where the desired quantities were measured through the case study strategy. The required tools are the base and

analytical maps, and part of the basic data was gathered through the field study, aerial photos and GIS software. Climate change in cities has led to rising temperatures, falling rain, drought, and so on, and undoubtedly, these effects will be increased in the future. The strategic use of green infrastructure in cities in the form of rows of trees in streets, parks, roofs and green facades, in the first place, can lower the temperature and confrontation with the drought phenomenon in cities, and, in the second place, can reduce air pollution and prevent the loss of biodiversity in cities (Bosomworth et al., 2013).

Although the most common application of vegetation in different types is further seen in the hot and arid areas, no precise strategies have yet been adopted for the proper use of vegetation in these areas by the urban planners and managers. The method used here can be called ‘CRGIIM’ (Climate Resilience through Green Infrastructure Implementation Method). It is required to make some changes in this method according to climate conditions, plant species and soil conditions of the area in terms of country, city and geographical location.

This method will attempt to achieve a framework for prioritizing and selecting the proper green infrastructure affecting the neighbourhoods. This is the first method in which the main focus is on the street geometry, location of green infrastructure and type of selected plant species to establish a link between the spatial location, quantity and quality of vegetation and the enhancement of climate resilience on neighbourhood and street scale. The CRGIIM method explores the relationship between urban geometry, urban green infrastructure, temperature reduction and adjustment, reduced air pollution and impact of climate change on drought based on geographical location of the selected city, as the case study, and the fact that the city facing climate change and its effects, has major issues, including air and water pollution, temperature rise and drought (Norton et al., 2015). This method consists of six steps:

1. Prioritize neighbourhoods and choose a neighbourhood with a higher priority,
2. Identify and categorize green and gray infrastructure existing in neighbourhood,
3. Use and strengthen existing green infrastructure to adapt to climate change and increase climate resilience,
4. Sequence and prioritize streets in a neighbourhood based on strengthening of existing and new green infrastructure,
5. Select new and appropriate green infrastructure taking current situation of neighbourhood and its climate potential into account, and
6. Accurately locate green infrastructure of neighbourhood by analysis of green patch, corridor and matrix situation (Norton et al., 2015) (Figure 4).

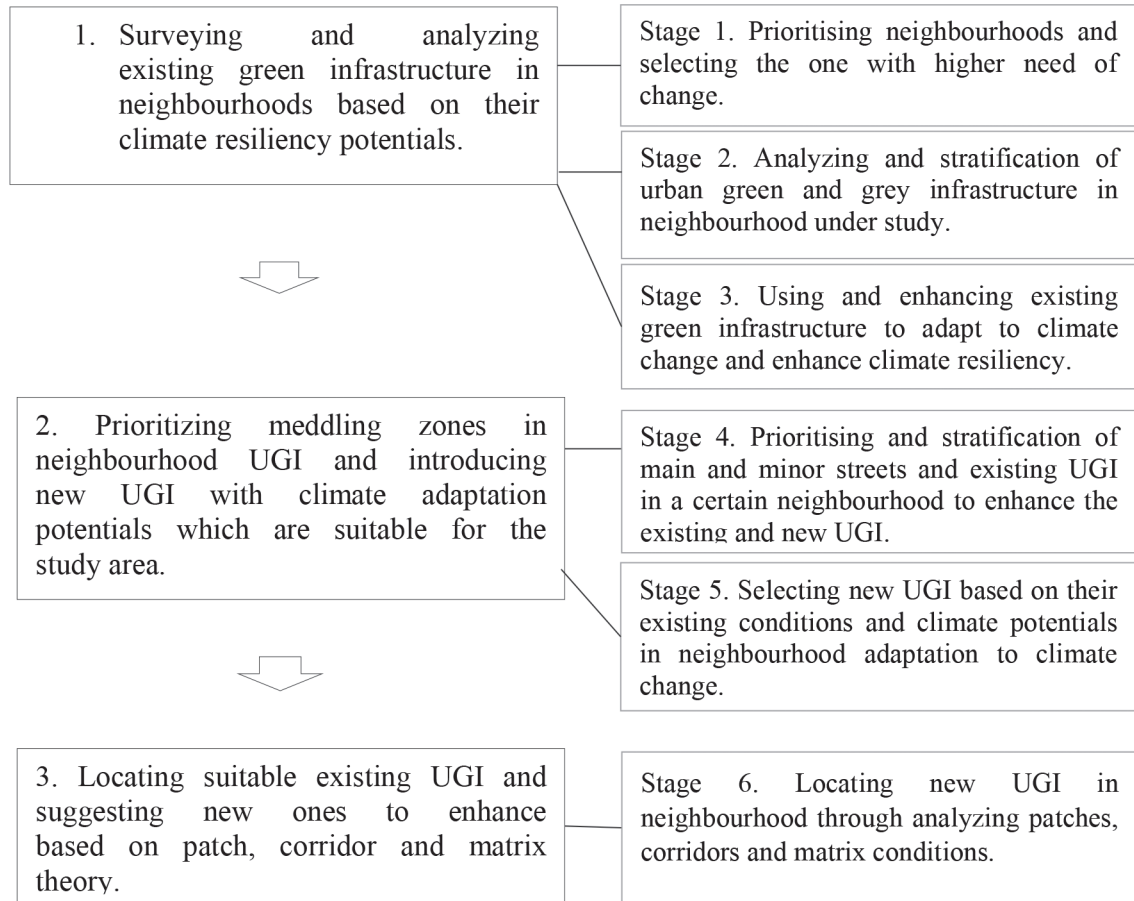


Figure 4: Defining a three-stage method (with six sub stages) of interfering in UGI in neighbourhoods in order to enhance climate resiliency in this scale (Shirgir et al., 2019; Gill et al., 2007; Norton et al., 2015).

Here, the tools are base and analytical maps produced in GIS software. The required base maps include: width to height ratio of buildings in the neighbourhood (H:W), thermal data of neighbourhood, current situation of the green infrastructure in the neighbourhood, map of the situation of grey infrastructure in the neighbourhood, and the final analytical map including the priority map for the intervention in the green infrastructure of Yousef Abad neighbourhood, based on climate resilience. Figure 5 shows the scales affected by this method.

Area of Study: Yousef Abad Neighbourhood of Tehran

Tehran, the capital city of Iran, is a city with major problems due to climate change and urbanization. The most important problems caused by such changes in Tehran are drought, flood, temperature change, water shortage and contamination, air pollution, storm and dust.

Yousef Abad area of Tehran is one of the oldest and most famous neighbourhoods of Tehran located in the 6th district of the city (Figure 6). According

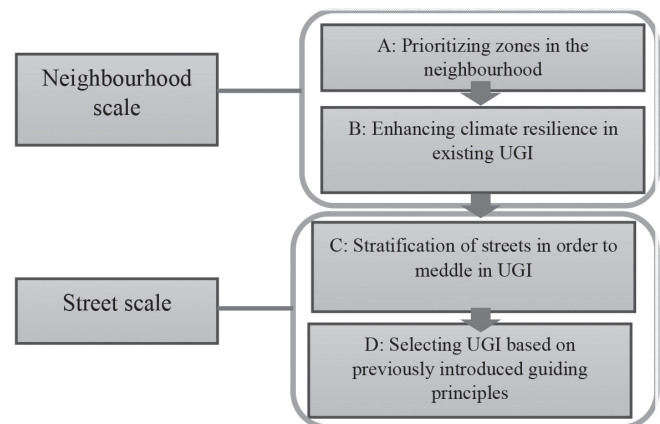


Figure 5: CRGIIM and its effective scales (Norton et al., 2015).

to the reviews conducted in this neighbourhood, the main streets are mostly north-south oriented and the secondary streets are east-west oriented, which will affect the amount of light and heat received throughout the day. Seyed Jamal al-Din Asad Abadi Street is considered the most important north-south main street

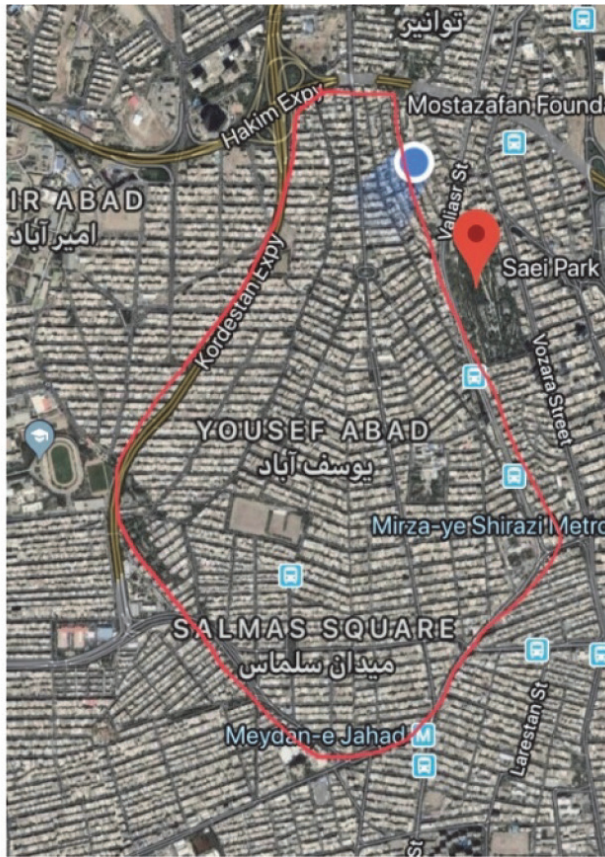


Figure 6: Tehran, Yousef Abad neighbourhood aerial photo (Google n.d., 2019).

and Fathi Shaghghi Street as the most important east-west secondary street. The main and secondary streets are approximately perpendicular and constitute a network structure. All the maps are on 1:9000 scale.

Results

Here, the six-step framework mentioned in Figure 4 will be described for Yousef Abad quarter.

Step I. Prioritize neighbourhoods and choose a neighbourhood with a higher priority for intervention in green infrastructure: For this step of the research, thermal map of Yousef Abad neighbourhood was prepared to prioritize the neighbourhood in terms of climate resilience based on the situation of urban green infrastructure. In this map, the thermal condition of Yousef Abad is displayed in five main classes, ranging between 32°C and 41°C. It is evident that the regions with higher temperatures are those receiving more light and heat due to the lack or absence of green spaces and geographic direction. In data analysis section, these points and areas will be determined as the high priority

points for the intervention in the current situation using a method that will be described later.

Step II. Identifying and categorizing green and gray infrastructure existing in Yousef Abad neighbourhood considering climate potential: To carry out this step of the research, the base maps of the current situation including the map of grey infrastructure (squares, main and secondary streets) and the situation of the existing green infrastructure (trees, green garden patches, parks, etc.) were prepared.

Step III. Using existing green infrastructure in Yousef Abad neighbourhood for adaptation to climate change and increase of climate resilience: At this step, to achieve a method for assessing and analyzing the current situation and achieve a method for intervening and strengthening the current situation of green infrastructure in the Yousef Abad neighbourhood, a map was prepared which, in addition to the location, the health status of plant species in the area was also examined. In the analysis section, the unhealthy plant species were removed and healthy plant species, appropriate for the climatic conditions of Tehran, were recommended for this region (Table 2). The type of existing plant species along with their specific characteristics, including the water demand, resistance to climate conditions, shading level, number, etc., are also presented in Table 1. The map of green infrastructure of Yousef Abad reviews the health status of three main tree species such as Planemulberry, Eldarpine and European ash as three relatively dominant plant species in the neighbourhood.

Step IV. Sequencing and prioritizing streets in Yousef Abad based on strengthening of existing and new green infrastructure: The ratio of building height to street width (H:W) is a suitable method for analyzing the amount of light and thermal energy received by the streets. This ratio represents the amount of building shading on the street. The smaller the ratio, the more heat the street receives during the day, whereas the higher the ratio, the deeper the shade put on the street by the buildings. However, if this ratio is low, the east-west streets receive more hours of direct sunlight during the day, while the north-south streets receive the light only in the limited hours. To analyze this situation, several maps were prepared including: map of street width in metres, average height of buildings, map of number of building floors, and finally, map of calculation of the height-to-width (H:W) ratio of buildings (Figure 7).

Step V. Prioritizing intervention area in existing green infrastructure and introducing new and appropriate

Table 1: Plant cover analysis in Yousef Abad neighbourhood based on the degree of climate resiliency*

<i>Scientific name</i>	<i>Number</i>	<i>Location (On main or secondary street) (Northern-Southern street or Eastern-Western)</i>	<i>Shadowing capacity</i>	<i>Tolerance to air pollution</i>	<i>Watering need</i>	<i>Health conditions</i>
<i>Platanus</i> spp. (<i>Platanus orientalis</i>)	Majority	Main/Northern-southern	Little	Very tolerant	A lot	Unhealthy
<i>Morus</i> spp. (<i>Morus alba</i>)	Majority	Main/Northern-southern	A lot	Non-tolerant	A lot	Healthy
<i>Ailantus altissima</i>	Limited	Main/Northern-southern	Little	Very tolerant	Low	Healthy
<i>Cercis siliquastrum</i>	Limited	Main/Northern-southern	Little	Very tolerant	Low	Healthy
<i>Robinia pseudacacia</i>	Limited	Secondary/Eastern-Western	A lot	Very tolerant	Low	Healthy
<i>Ulmus carpinifolia</i>	Limited	Secondary/Eastern-Western	A lot	Non-tolerant	Low	Unhealthy
<i>Pinus eldarica</i>	Limited	Main/Northern-southern	A lot	Very tolerant	Low	Unhealthy
<i>Cupressus sempervirens</i>	Limited	Main/Northern-southern	Little	Very tolerant	Low	Healthy
<i>Fraxinus exelsior</i>	Limited	Main/Northern-southern	A lot	Non-tolerant	Low	Healthy
<i>Ficus carica</i>	Limited	Main/Northern-southern	Little	Non-tolerant	A lot	Healthy
<i>Populus deltoides</i>	Very Limited	Main/Northern-southern	A lot	Non-tolerant	A lot	Healthy

* **About the importance of location:** Prioritisation of main and secondary streets are an important factor, since they display the amount of solar radiation the streets are exposed to during the day, and how warm it gets. The streets that are northern-southern usually get more sun and are warmer; therefore they need plants with higher shadowing capacity.

Shadowing capacity: The amount of shade trees provide depends on their architectural form and canopy density. These can all be listed in a field survey in small areas such as neighbourhoods (Pataki et al. 2011). Thick or dense canopy trees provide good shade, meaning that broad leaf trees are generally more effective than needle-leaf trees (Leuzinger et al., 2010).

Tolerance to air pollution: Some trees are more tolerant to air pollution; that's why they are a proper choice for a city like Tehran with severe air pollution challenge.

Watering need: Also, water demand is an important factor, and the trees are water stressed. Stress from low water availability during hot weather can lead to defoliation and possibly death (Gill et al., 2007). Therefore by examining the existing plants health status, it can be cleared that some plants are not suitable for the existing climate conditions and the amount of irrigation water available in the area (Coutts and Harris, 2013).

Plants health conditions: Vegetation health information obtained from on-ground study and GIS based maps, can be used most efficiently to enhance existing UGI. Shading capacity in trees depends on both trunk and branches, as well as, the leafy canopy. Therefore the healthier the plants are the more shading and cooling benefits they will have (Norton et al., 2015).

-The data about green species climate resilience characteristics were derived from the book by H. Sabeti in 2008, called Forests, trees and shrubs of Iran and also from the author's knowledge of the green species characteristics based on her background in the field of landscape architecture.

green infrastructure based on their climate resilience potentials in Yousef Abad neighbourhood of Tehran: At this step, the analysis and interpretation of the collected data are performed. Different layers were used to prepare the maps (tree species layer, green space layer, street layer and thermal map layer of Yousef Abad in Tehran). By overlaying the information of each of the base maps and rating with Arc Map software, an analytical map was prepared in nine categories designated as the priority map of the intervention area in the existing green infrastructure located in the Yousef Abad neighbourhood of Tehran (Figure 8). In this map, the main priority for the intervention is displayed by

1 and the lowest priority is displayed by 9 in the map legend. In this way, Asad Abadi Street was displayed as the first area of intervention.

As a result, by analyzing the height-to-width ratio, this street receives the highest amount of light during the day, and, as seen in the thermal map, it has a high temperature. Therefore, it is necessary to review the situation of green infrastructure, tree species and vegetation, gardens and parks, etc. along the street and also to provide suggestions and principles for strengthening and maintaining the status of these elements.

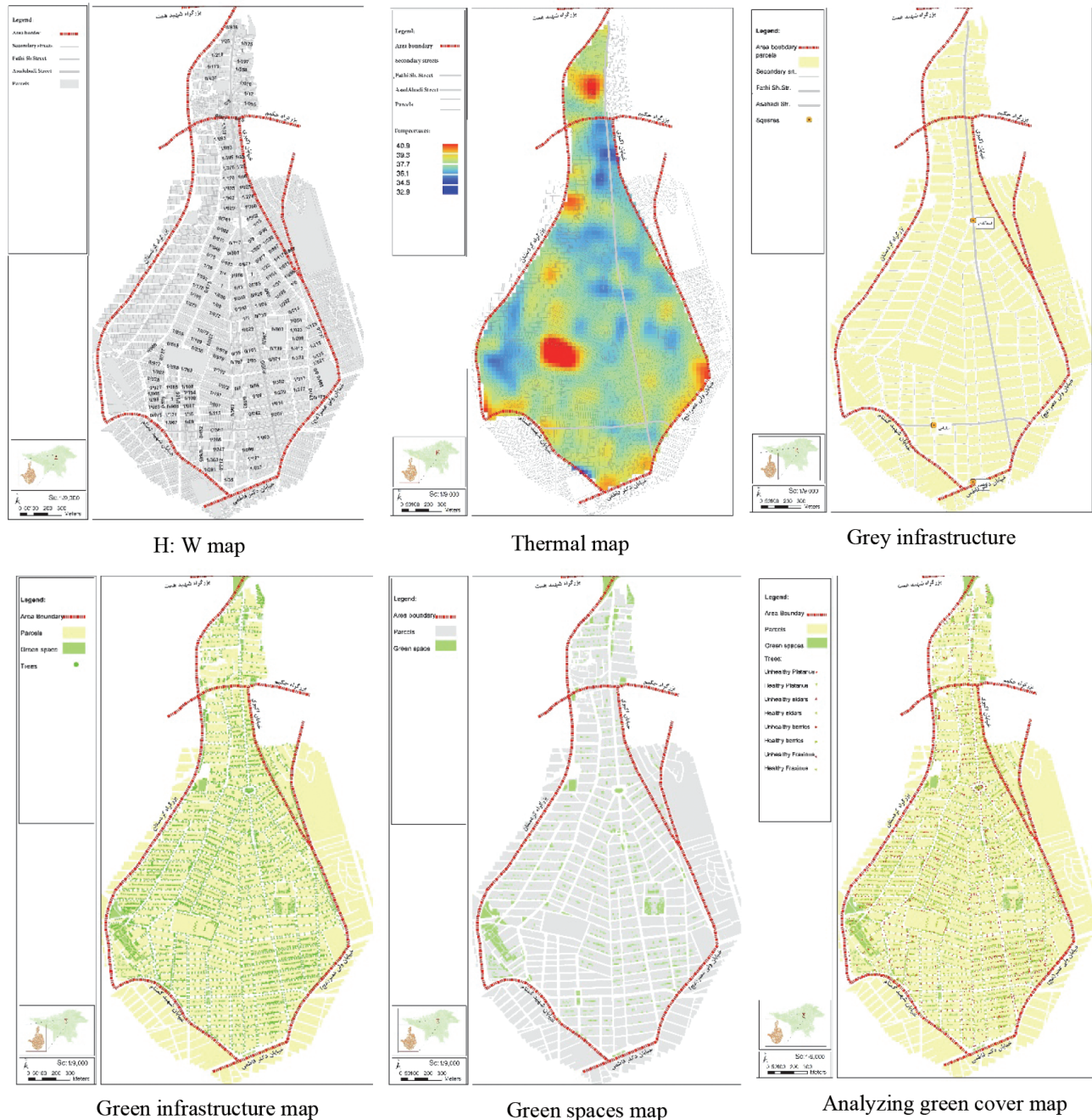


Figure 7: Base maps.

Step VI. Introduction of proposed plant species resistant to climate change with potential of resilience to water shortage, air pollution and high temperature in Yousef Abad neighbourhood of Tehran: After reviewing the situation of vegetation in Yousef Abad, a table was prepared where the plant species were proposed with high potential for resilience to climate change (Table 2).

Step VII. Properly locate new and strengthened green infrastructure using patch, corridor and matrix

(Landscape ecology theories) (correct location of proposed green infrastructure): Now, regarding the location, patches, green corridors and matrices in the Yousef Abad quarter, the analysis were made on the aerial photos, which are presented here. The current situation of the green patches, corridors and matrix in the Yousef Abad quarter of Tehran is presented in the left side aerial photo. Based on the theoretical foundations, the more continued and greater number the corridors

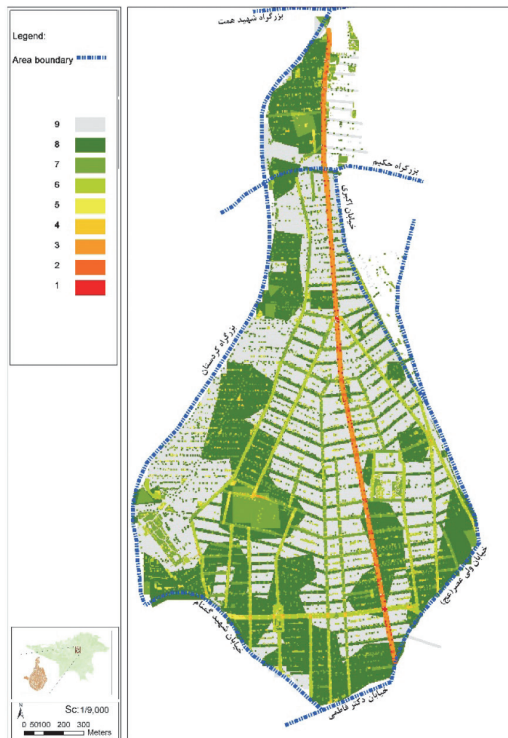


Figure 8: Prioritization map of intervention in Tehran's Yousef Abad's UGI.

and the wider and more interrelated the patches and the more continued the matrix in this neighbourhood, the higher the climate resilience of the quarter. Based on the principles, the proposed model was provided in the right side in terms of the patch, corridor and matrix for the Yousef Abad quarter.

By integrating the proposed matrix with the proposed plant species of the appropriate climate potential for a neighbourhood, new locations can be proposed for the situation of urban green infrastructure in a neighbourhood along with resilient species. This method can also be used to locate the green patches and plant species in new urban projects. The aerial photos and the interpretation of the proposed existing green patches, corridors and matrix are presented in Figure 9.

Discussion

Some of the most important findings of this research are: The importance of climate resiliency in the 'neighbourhood scale' was emphasized on. Most of the existing literature are focused on the city scale whilst the neighbourhood scale is more important as the core element of cities.

Table 2: Suggested plant cover for Yousef Abad with emphasis on increasing climate resiliency*

<i>Scientific name</i>	<i>Suitable for Northern-Southern/ Eastern-western streets/Main or minor</i>	<i>Tolerant to heat/ Good shadowing capacity</i>	<i>Tolerant to air pollution</i>	<i>Tolerant to drought</i>
<i>Ailanthus alissima</i>	Eastern-Western (Secondary)		★	
<i>Albizzia julibrissin</i>	Eastern-Western (Secondary)		★	
<i>Celis avstruliss</i>	Eastern-Western(Secondary)		★	
<i>Robinia pseudoacacia</i>	Northern-Southern (Main)	★	★	
<i>Fraxinus excelsior</i>	Northern-Southern (Main)	★		★
<i>Ligustrum vulgare</i>	Northern-Southern (Main)			★
<i>Cupressus sempervirens</i>	Northern-Southern (Main)	★		★
<i>Pinus longifolia Roxb</i>	Northern-Southern (Main))	★		
<i>Eleagnus angustifolia</i>	Eastern-Western (Secondary)			★
<i>Gleditsa triacanthos</i>	Northern-Southern (Main)/Eastern- Western (Secondary)	★		★
<i>Quercus rubra</i>	Northern-Southern (Main)/ Eastern- Western (Secondary)	★		★
<i>Betula verrucosa</i>	Northern-Southern (major)/ Eastern- Western (Secondary)			★
<i>Salix alba</i>	Northern-Southern (Main)/ Eastern- Western (Secondary)	★		★
<i>Melia azedarach</i>	Eastern-Western (Secondary)	★		
<i>Pyracantha</i> sp.	Northern-Southern (Main)/ Eastern- Western (Secondary)		★	★
<i>Crataegus</i> sp.	Eastern-Western (Secondary)		★	★
<i>Lonicera</i> sp.	Eastern-Western (Secondary)			★

*The data about green species climate resilience characteristics were derived from the book by H. Sabeti, 2008, called Forests, trees and shrubs of Iran and also from the author's knowledge of the green species characteristics based on her background in the field of landscape architecture

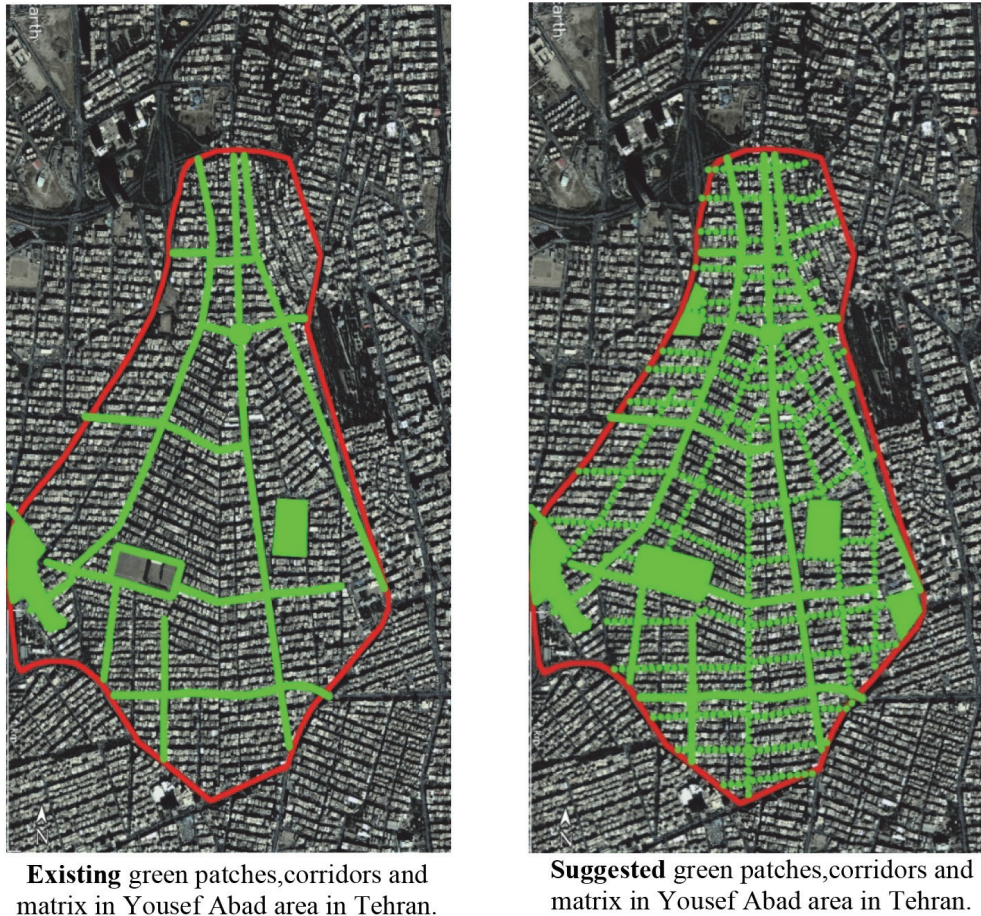


Figure 9: Existing and suggested green patches, corridors and matrix based on the science of landscape ecology (green patches, corridors and matrix) (Shirgir et al., 2019).

Climate resilience is almost a new concept that has been introduced; it needs to be more elaborated as a type of resilience. Most research has been on social and ecological resilience but not a lot has been done on this type of resilience. The role of UGI in neighbourhood scale was also presented. Not a lot of research has been done on this scale.

Also strategies for adaptation to climate change and improvement of climatic resilience using urban green infrastructure, were derived from the existing literature, which were the first steps of doing research in the field of UGI in city scale.

UGI meddling solutions framework to enhance climate resilience in neighbourhood scale based on climate change adaptation strategies in city scale were presented here.

Defining a three-stage method (with six sub stages) of interfering in UGI in neighbourhoods in order to enhance climate resiliency in this scale was mentioned here by combining strategies for adaptation to climate

change based on UGI role on climate resilience with the six-step method mentioned earlier in this research.

Introducing “climate tolerant plants”, whether drought tolerant or any kind of tolerance related to the climate challenge that a city is facing for the specific city of Tehran and most importantly at the neighbourhood scale. This way climate resiliency of the new or existing UGI can be ensured. This strategy can be specified to cities or neighbourhoods facing drought and drier climates due to the recent climate changes. Choosing the right plant types are also very important, different plants survive in different climates and they vary in each city or region. According to the studies done for this paper, this step, which is providing a list of plant species that could ensure resilience to climate conditions, has not been done officially as of today. This could be a step to further the studies done on UGI and urban resilience. Also analyzing the plantings of an area based on their climate resilience potentials has not been done at all. So this could be a step forward in the field of using UGI for facing climate change challenges.

By using Forman and Gordon's landscape ecology principles as a reading language, the design and location of the UGI and on the whole their existing situation, can be translated into patches, corridors and matrixes in a city or neighbourhood scale. This is a language that can be used to read the existing situation of UGI and to develop principles to enhance this situation into a more climate resilient city. It can be concluded that the characteristics of UGI that could be used to do the analysis are: Their number, location, covering area, health status, and type of species. The more the climate resilient plants are used the more the tolerance, the more the green patches are connected and green corridors are continuous the greater the climate resilience, the more areas are covered with proper green species the higher the tolerance, the healthier the plants and green species the better their function in reducing climate change effects (especially heat waves and thermal discomfort), and the more tolerate types are used the more the tolerance will be. Further studies need to be done to elaborate these quantities and their measurement and assessment.

One of the most important points here is that the strategies and the method, that were mentioned earlier which are related to green urban infrastructure and their role on adapting to climate change conditions, can be applied to cities or neighbourhoods and on the whole to countries facing four major climatic challenges which are: Drought, Extreme Heat, Precipitation Reduction and Water Shortage.

Regarding the green infrastructure in particular, it can be stated that the analysis of the situation of plant species in a region based on the type of plant species, location, covering area, number and amount of these species and health status of plant species, and comparison of these factors, can be a proper way to analyze the potential of climate resilience in the green infrastructure of an area in a city.

In principle, for the first time, in this research, a 'qualitative-quantitative' method was obtained for assessing the situation of green infrastructure based on climate resilience and changing of this green infrastructure in order to increase the climate resilience.

Given the findings of the theoretical foundations and the strategies of adaptation to climate change through the green infrastructure presented in the final section of this paper, the framework proposed for the intervention in urban green infrastructure is fully consistent with the strategies, and by integrating the city scale strategies with the proposed neighbourhood scale intervention framework, some principles can be

obtained to enhance the climate resilience by utilizing the green urban infrastructure on the neighbourhood scale to reduce drought, temperature rise, air pollution and water shortage.

By having a neighbourhood resilient to climatic conditions, it can be claimed that a city's resilience to these conditions can also be guaranteed.

Conclusion

Urban green infrastructure and their role in urban design and planning have not yet been properly elaborated. While it is proven that the use of urban green infrastructure is one of the key strategies to reduce and adapt to climate impacts in the areas with Mediterranean, hot and arid climates, the exact strategies for the correct use of these infrastructures in the cities have not yet been provided.

Here, by conducting this research on Tehran, a framework was obtained for documenting and measuring the quality and to some extent the quantity of urban green infrastructures in order to enhance the quality and the adaptation to climate change. It is hoped that this method could be generalised to the cities and neighbourhoods according to the geographic location and the negative impact of the particular climate change. Obviously, more research is needed to generalise this method to other cities.

Having studied the literature on this subject, there seems to be a lack of research on the neighbourhood scale, most studies are aimed for the city scale. So this is the first attempt to find a theoretical method to first analyze and improve the UGI conditions in this scale in order to build a more resilient neighbourhood.

Further studies need to be done on analyzing the *quantitative* characteristics of UGI in order to be able to analyze them quantitatively; these characteristics, when clarified, can be of great help to assess the climate resilience of cities and neighbourhoods, especially on old and new projects, since there seems to be no studies on this matter so far. So the method and frameworks presented here are one of the first stepping stones into the assessment process of climate resilience in cities.

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