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Developing Strategic Principles of Intervention in Urban Green Infrastructure to Create and Enhance Climate Resilience in Cities—Case Study: Yousef Abad in Tehran

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Abstract: Currently cities all over the world are facing a wide range of hazards. These risks are exacerbated by factors such as increasing urban population and climate change. Urbanism and climate change are closely interlinked. Meanwhile, the concept of urban resilience has been introduced, in recent years, to reduce these negative impacts. Resilience is the ability of a system to absorb abnormalities while its basic structure is maintained when at risk. Resilience to climate change focuses on reducing vulnerabilities to these changes. The current research focuses on urban ecological resilience and its subsection of 'climate resilience' and also climate change adaptation strategies.

Urban green infrastructure is also effective in reducing the impacts of climate change and enhancing climate resilience in cities. In the face of dangers such as climate change, the resilience approach can be used as a framework for intervention in existing and suggested urban green infrastructures and vice versa.

This research attempts to answer this question: How can intervention in urban green infrastructure (their quality and quantity, maintaining, enhancing and location) lead to developing strategic principles to ensure an urban climate resilient city in times of drought, extreme heat, low annual precipitation and water shortages? The purpose of this research is to develop strategic principles for adaptation to climate change using green infrastructure and their capabilities to enhance urban climate resilience in dry countries. A qualitative method was used here by using aerial photos and producing GIS base and analytical maps of Yousef Abad neighbourhood in Tehran, the capital city of Iran, which lead to producing the above mentioned principles.

Keywords: Urban green infrastructure; Urban climate resilience; Climate change adaptation strategies; Climate change.

Introduction

Disasters have a negative impact on human life. This increasing trend of disaster losses is due mainly to the unprecedented rate of urban growth, increasing dependence on complex infrastructures and changes in climate that are increasing exposure to anthropogenic and natural hazards (Amaratunga, 2018). In response, individuals and communities are working to reduce the consequences of these disasters and to scale up the impact of the disaster, as well as to meet the needs after them and return to initial response conditions. Natural disasters are one of the main repeatable challenges for developing countries which not only cause deaths of people, the physical and emotional suffering of survivors, but also seriously damage the local economies. Hence, scholars, academic experts and planners try to base their approaches and patterns on

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developing appropriate plans to reduce the damages to natural disasters (IPCC, 2008).

One of these approaches is to investigate the extent of 'resilience' to natural disasters. Today, natural disasters occur due to climate change which is a wide-spread phenomenon taking place all over the globe. Cities all over the world face a wide range of hazards, which are aggravated by factors such as increasing urban population and climate change (Bogunovich, 2009). On the other hand, resilience is a new concept that is most often used in the face of unknowns and uncertainties, such as climate change (Adhya, 2010).

Climate change adaptation strategies are developing through recent studies. They include reducing the negative and adverse impacts of climate change and even the effects that are expected to occur in the future (Leichenko, 2011). Also, concepts of resilience and resilient cities have been introduced to reduce these negative effects in recent years. Resilience is the ability of a system to absorb abnormalities while its basic structure is maintained and its functionality has the capacity for self-organization and adapting to stresses and changes (Connell et al., 2017).

Cities are the main focus of the human population in the current world. 'Resilient City' is a dynamic, consuming, changing and energy-producing urban ecosystem which is coordinated with other ones. It has adaptive approaches to become resilient to climate changes and to reduce them and it also supports development in infrastructure and socio-economic life. Resilient city has the capability to encounter danger and has economical sustainability. This city has adaptation and reduction methods and is made of a sustainable physical network of natural and artificial human communities. One of the subsections of urban resilience is urban ecological resilience (Leichenko, 2011).

Urban ecological resilience was defined as the amount of disturbance that an ecosystem—city—could withstand without changing self-organized processes and structures (defined as alternative stable states) (Schipper, 2007). Ecological resilience is also divided into subsections, the one in focus of this paper is 'Climate resilience'. It is a resilience to climate changes and to vulnerability to these changes. 'Climate resilience' is generally defined as the capacity for a socio-ecological system to: (1) absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts (Tyler and Moench, 2012).

On the other hand, urban green infrastructure (UGI) has many vital functions, including environmental and social performances. Green infrastructure is effective, economical and enhances community safety and quality of life (Byrne et al., 2015).

This article tries to discuss and declare the strategies with which urban green infrastructure can enhance climate resiliency in cities, by focusing on the main question, principles and strategies of dealing with existing and future urban green infrastructures will be developed using existing theories and scientific documents. The research method is using quantitative approach and content analysis of existing documents; comparisons are made and lack of sufficient information were detected in the areas mentioned above; and the general principles and theoretical framework of the discussion were developed in order to overcome the so called scientific gaps. Also a qualitative method was used by using aerial photos and producing GIS base and analytical maps of Yousef Abad neighborhood in Tehran, the capital city of Iran, as tools which lead to producing the above mentioned principles.

Theoretical Framework

According to what was mentioned in the previous section, the concepts of climate change, adaptation and mitigation strategies to climate change, climate resiliency, urban green infrastructure and the relationship between them will be discussed here.

Climate Change in Cities

Climate change has been affecting people around the world, threatening the basic elements of life access to water, food, health and use of land, and the basic environment (Mishra, 2017). Certain human activities have been identified as primary causes of ongoing climate change including urbanism. There is no general agreement in scientific, media or policy documents as to the precise term to be used to refer to anthropogenic forced change; either global warming or climate change may be used. Climate change is a global phenomenon that largely impacts urban life. Rising global temperatures causes sea levels to rise, increases the number of extreme weather events such as floods, droughts and storms, and increases the spread of tropical diseases (Asian Development Bank, 2010).

Today, the direct and indirect effects of climate change on low-income and middle-income residents can be seen in countries with the lowest role on global warming and climate change. The effects of

urbanization and climate change are converging in dangerous ways. On the other hand, cities are major contributors to climate change: although they cover less than 2 per cent of the earth's surface; cities consume 78 per cent of the world's energy and produce more than 60% of all carbon dioxide and significant amounts of other greenhouse gas emissions, mainly through energy generation, vehicles, industry, and biomass use (Klein et al., 2003).

At the same time, cities and towns are heavily vulnerable to climate change. Hundreds of millions of people in urban areas across the world will be affected by rising sea levels, increased precipitation, inland floods, more frequent and stronger cyclones and storms and periods of more extreme heat and cold. In fact, many major coastal cities with populations of more than 10 million people are already under threat (IPCC, (2007).

From what is said it can be concluded that climate change and cities have impacts on each other, direct and indirect. Due to these conditions taking adaptive actions to face climate change in cities are essential.

Many cities are already doing a lot by using renewable energy sources, cleaner production techniques and regulations or incentives to limit industrial emissions (World Bank, 2011). Cutting emissions will also reduce local pollution from industries and transport, thus improving urban air quality and the health of city dwellers (Asian Development Bank, 2014). It is important to mention the fact that different countries face different climatic changes according to their geographical location, climate, population, width and so on. Some countries face the same changes and some face very different ones. In this paper, countries facing drought, extreme heat, and low annual precipitation, water shortages and on the whole dry cities and countries are in focus. One of the adaptive strategies is using urban green infrastructure (UGI) in ways to reduce climate change impacts in cities. These strategies will be discussed later in this paper.

Climate Change Adaptation and Mitigation Strategies and Their Connection with Resilience

Climate change adaptation and mitigation are main strategies for addressing the dangers of climate change. They are more about reducing the amount of greenhouse gas pollution and the natural and unnatural processes that contribute to this decline. The strategies for adaptation to climate change include addressing negative impacts of climate change and even the effects that are expected to occur in the future. Both of these strategies are working to control and balance climate change and make the world better for future generations in accordance with the principles of sustainability. Adaptation strategies will be the only response available for climate change in the coming decades, before climate reduction approaches can be effective (Carter et al., 2015).

As a result, adaptive strategies seem to be needed to resolve the crisis that require quick responses and encounters. Here one can see the relationship between adaptations with the concept of resilience. The results of climate change reduction strategies are not immediately visible because reducing greenhouse gas emissions are a long-term trend (Connell et al., 2017).

The functions of climate change mitigation strategies affect the world, even if they are intended only for a neighbourhood in a small city, while adaptation is carried out at the scale of a crisis-hit system. The target sectors are limited in adaptation strategies, including energy, transportation, heavy industries and agriculture, while adaptation strategies involve a variety of sectors that include human health, water supplies, urban planning and coastal management (Walsh et al., 2011). Generally, adaptation to climate change are used for accidents and disasters that require short-term confrontation. The framework for the relationship between adaptation to climate change in cities, vulnerability and the dangers of climate change have been outlined in Figure 1 (Carter et al., 2015).

As seen in Figure 1 adaptation capacities lie in the information and governance sector. Also the most vulnerable sectors are infrastructures, the societies and buildings. Green infrastructures can be of use to adaptation if closely studied and standardized in different scales especially in the neighbourhood scale.

In Figure 1 the relationship between resilience, sustainability, climate change adaptation and mitigation strategies are displayed. As seen, resilience strategies lead to a greater goal which is sustainability. Sustainability approaches are used for longer term goals while resilience approaches are for facing shocks and making quick decisions to rescue a system and to help it to return to conditions before the crisis. Climate change adaptation and mitigation strategies also lead to a more resilient system. As mentioned before, since adaptation strategies are used for achieving short term goals, resiliency seems to be in the adaptation category more than it is in the mitigation one. Having discussed climate change and its adaptation strategies, the term 'climate resilience' can be defined now.

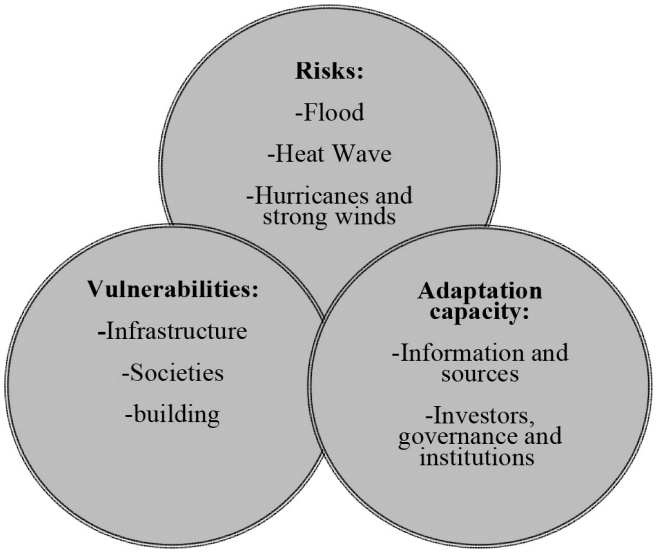


Figure 1: The framework for the relationship between adaptation to climate change in cities, vulnerability and the dangers of climate change (Carter et al., 2015).

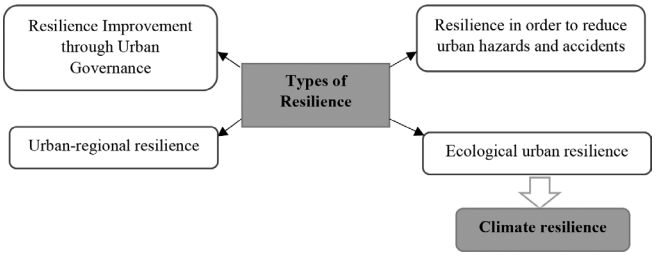


Figure 2: The relationship between climate resilience and resilience types.

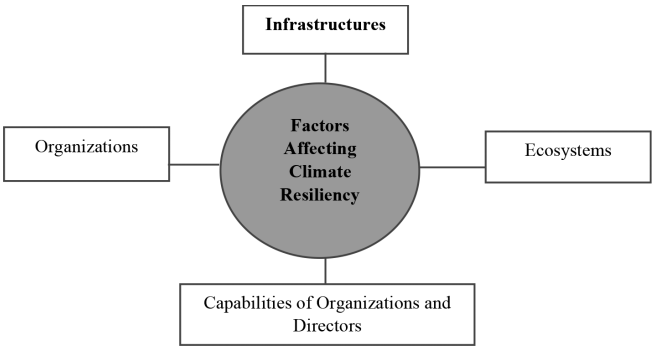


Figure 3: Effective factors on climate resilience.

Climate Resilience

The concept of resilience proliferates in fields as disparate as psychology and information technology, as far-flung as ecology and business. There are probably hundreds of definitions of resilience in existence, and the term itself connotes shades of meaning outside its numerous denotative spotlights. In terms of climate change, resilience means strengthening the ability of human and non-human systems to withstand and respond to changes in the earth's climate, and it can be thought of as a way to bridge the conceptual division between mitigation approaches to climate change on the one hand and adaptation approaches on the other. As said in the introduction section, climate resiliency is a type of urban-ecological resilience (Childers and Cadenasso, 2015) (Figure 2).

Climate resilience is the capacity of an independent unit or a group or organization to respond dynamically and effectively to climate change, while still maintaining an acceptable level of normal activities. This capability includes the ability to resist change, as well as post-shock recovery and reorganization to prevent the destruction of the system—city—and its survival (Dayland and Brown, 2012). In Figure 2, the relationship between climate resiliency and other types of resilience can be viewed.

In order to display the important role of UGI on climate resilience, effective factors on the creation and enhancement of climate resiliency is discussed in the following section.

Effective Factors on Creation of Climate Resiliency

Here, the factors that affect climate change will be discussed, along with recommended priorities for urban regeneration strategies, as appropriate. These effective factors are briefly presented in the form of a diagram in Figure 3. In studies by Condon et al. (2009), the importance of urban infrastructure as a factor contributing to Climate resiliency has been mentioned.

As seen in Figure 3, the factors influencing climate resiliency are: organizations and directors, ecosystems, infrastructures which are of different types. One of these urban infrastructures is urban green infrastructure (UGI) which will be more explained in the following paragraphs.

Urban Green Infrastructure (UGI) and Its Adaptive Role on Climate Resilience

Green infrastructure also serves to provide an ecological framework for social, economic and environmental health of the surroundings. Green infrastructure is considered a subset of sustainable and resilient infrastructure. However, green infrastructure can also mean low-carbon infrastructure such as renewable energy infrastructure and public transportation systems (Derkzen, 2017).

To define UGI precisely, it can be said that nature can be used to provide important services for

communities by protecting them against flooding or excessive heat, or helping to improve air, soil and water quality. When nature is harnessed by people and used as an infrastructural system, it is called green infrastructure. Green infrastructure occurs at all scales. Green infrastructure also serves to provide an ecological framework for social, economic and environmental health of the surroundings. It is a type of social-ecological system that is the result of the interactions of various elements, especially human beings. As a result, proper interventions in these spaces can have a profound effect on everyday life. Resilient approach is one of the most proper approaches for intervention in such spaces. Urban green infrastructures are one of the most important 'Climate change adaptation strategies'. (Sheate et al., 2015). Different types of UGI that are in focus of this article are displayed in Figure 4.

Later on in this research, the importance of street trees, green gardens, green ribbons and jungle parks in forming green patches, corridors and in general matrixes to ensure climate resilience will be discussed. In cities, in order to create climate resiliency and to reduce emissions, there are multiple ways, one of them is to plan and design green spaces. For example, they can be very effective in controlling the flow of water during floods, creating shadow and reducing the heat

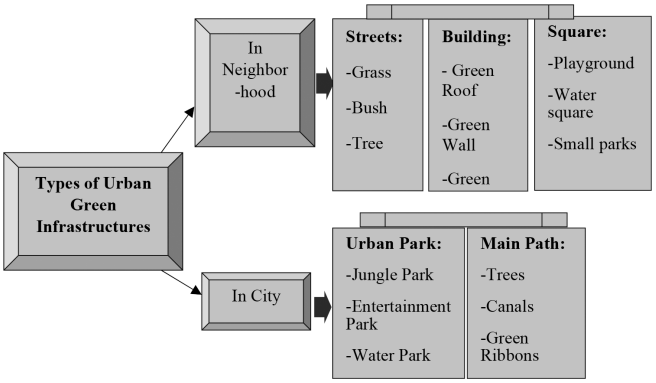
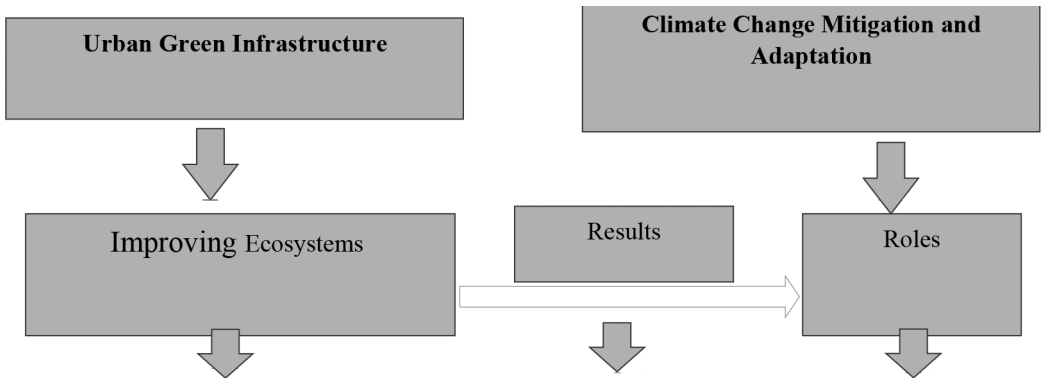


Figure 4: Types of green infrastructure in city and neighbourhood scale (Sheate et al., 2015).

and so on. In Table 1, the role of green infrastructure in reducing and adapting to climate change is displayed (Demuzere et al., 2014). According to Table 1, the role of green structures on reducing climate change impacts and increasing urban resiliency can be divided into several categories:

- Physical effects;
- Increasing temperature comfort and reducing energy consumption;
- Reducing the negative effects of floods and increasing water quality and reducing drought;

Table 1: Urban green infrastructure and their role on reduction and adaptation to climate change (Demuzere et al., 2014)



Roles of Urban Green Infrastructure	Physical Effect	Spiritual and Social Effects
• Carbon Storage • Climate Moderation • Water Flow Moderation • Treatment of Precipitation and Flood Water • Air filtration	• Reducing Carbon Dioxide • Temperature Comfort, Reduction of Energy Consumption • Reducing Flood and Drought-related issues • Water Quality Improvement • Air Quality Improvement	• Health and rehabilitation • Increasing Potential • Social and Individual Endurance

- Effect on air quality; and
- Positive psychological and social effects.

These roles have been presented in Figure 5 to show how these roles are effective in different scales in a city.

In Figure 5, the relationship between urban green infrastructure and its roles on climate change mitigation and adaptation has been demonstrated in three scales. This section was to prove and demonstrate the effects of UGI on climate change and urban resilience as a result.

After defining the keywords and phrases, it is time to analyze the relationships between them in order to reach a number of strategic principles, to analyze the existing green infrastructure in a city and to somehow introduce the most proper types of green infrastructure to reduce climate change effects it is time to do a sum up in the next section.

Climate Change Adaptation Strategic Principles: Using Urban Green Infrastructure (UGI) to Enhance Climate Resiliency in Cities

After studying literature in the field of key terms, the framework of climate change adaptation, strategies through the intervention and review of the existing situation of green infrastructure in cities, was achieved which will be discussed in the following paragraphs.

As it was mentioned before, it seems that using UGI as an adaptive strategy is mostly applicable in areas tackling with extreme heat, drought, precipitation reduction, air pollution and water shortage. These conditions seem to be generalizable to the current state of climate change in many countries around the globe with the same problems due to climate change. It is a fact that different countries face different types of climate change challenges according to their location and climate conditions, population and natural resources. This article is aiming for countries facing the above mentioned climatic challenges.

Adaptation strategies to climate change, regarding urban green infrastructure, have been summed up in three general strategic principles which is also presented in Figure 6.

Preservation and Enhancement of Existing Vegetation

One of the important strategies for reducing the temperature in the warm seasons is preservation and maintenance of existing vegetation whether in private gardens, public green spaces or in green spaces on the streets. There's a fact that in many urban areas, hard and built infrastructure already exist, and it is impossible to change their land use and replace them with large green

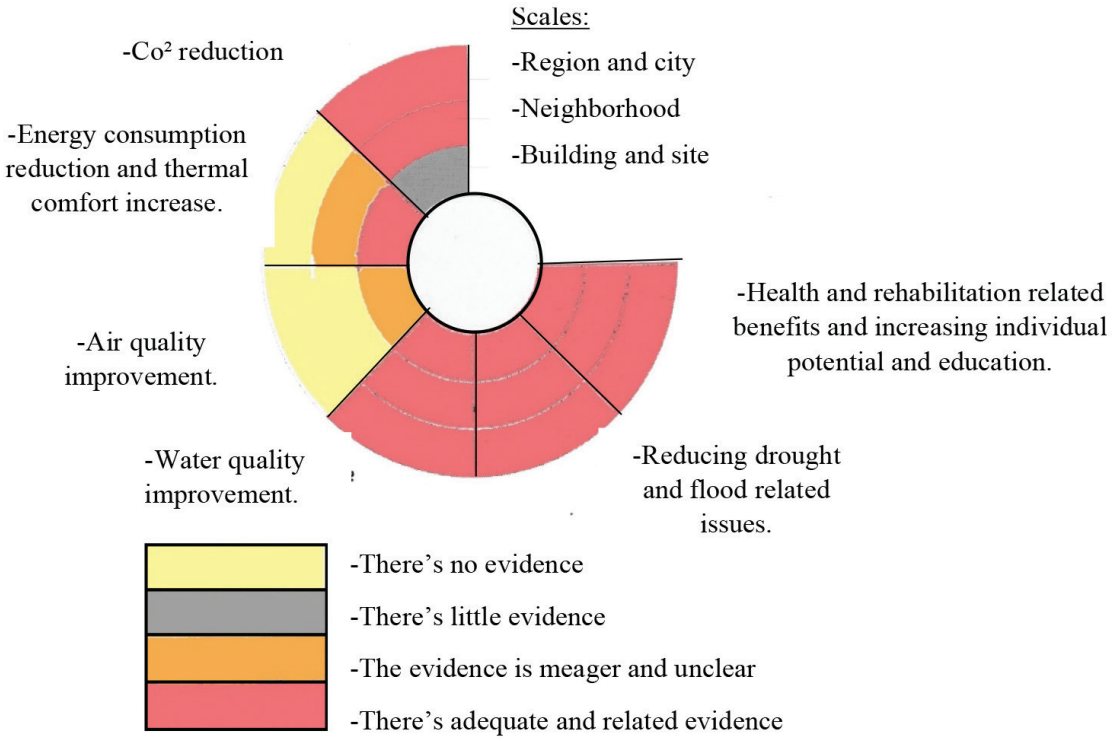


Figure 5: The link between the effects of urban green infrastructure and their impact on climate change reduction and adaptation in three scales and evidence-based sources (Demuzere et al., 2014).

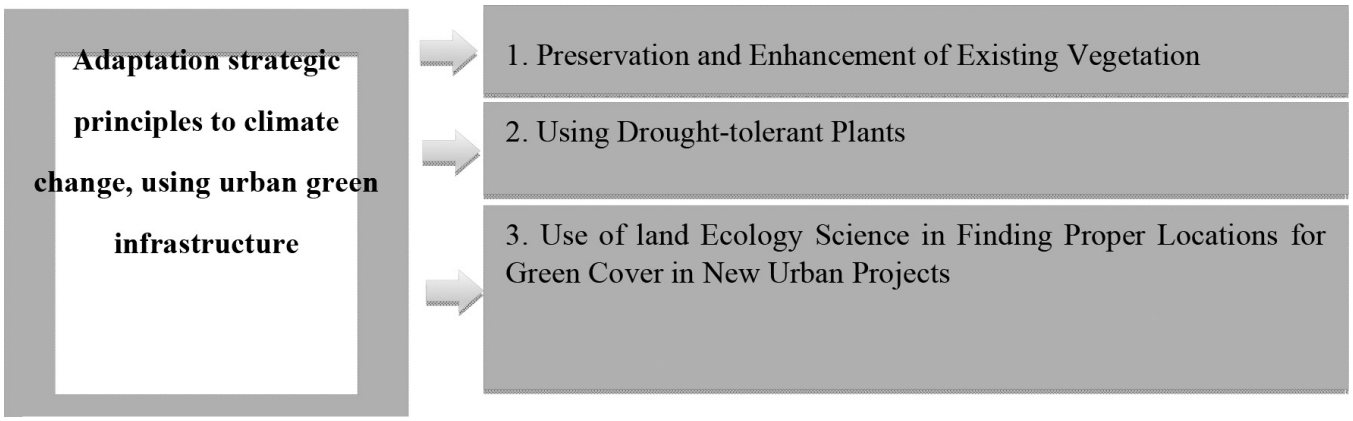


Figure 6. A framework for climate adaptation strategic principles using urban green infrastructure to improve climate resiliency in cities facing drought, extreme heat, precipitation reduction and water shortage.

spaces. In these circumstances, green infrastructure must be added to the environment creatively, using special methods.

Among these methods, the use of green roofs, green facades, planting of rows of trees along the streets and railroads and turning the streets into green corridors can be referred to. Priority should be given to areas where people's vulnerability to climate change is high. Areas with higher poverty, extreme heat, high population etc., are the most vulnerable.

Using Drought-tolerant Plants

Another strategy is the use of drought-tolerant plants. It goes without saying that one of the negative effects of climate change is causing droughts. Under such conditions, the use of plants with less water requirements and less susceptibility to climatic conditions is effective. Some types of plants are very resistant to specific climatic conditions, including drought. The use of trees is very suitable in such conditions. These plants continue to shade and evaporate under severe climatic conditions. To plant such trees on the streets, it should be noted that the roots of them have good space and conditions. In addition, their placement must be selected correctly. Conditions of irrigation are also very effective and it must be ensured that enough water will reach these trees. Water for irrigation of plants under drought conditions can be provided by reuse of gray or underground waters in the suburbs or by storing water obtained from flood and precipitation.

Use of Landscape Ecology for Green Infrastructures Locations

To deal with climate change, the location of the green infrastructures is very important. According to Forman and Gordon (1986), green infrastructures can be classified into three categories: Patch, corridor and matrix.

Each one of these types have their own benefits:

- Corridors are effective in storing flood water and controlling flood flow.
- Patches are more effective in storing rainwater during the outbreak of the rivers.
- Cooling of spaces through evaporation is done more by patches, than matrixes, and the creation of appropriate micro climates are done in patches.
- In the treatment of rain water, matrixes are more effective than patches. Green spaces, when they are more than one hectare, produce good micro-climates. Shadowing takes place in patches and matrixes, which leads to the cooling of residential areas. These facts are summarized in Table 2 (Gill et al., 2006).

Table 2: Typology of urban green infrastructure for adapting to climate change from the point of view of landscape ecology (Gill et al., 2006)

	Patch	*Corridor*	*Matrix*
Storing flood water	★★★	★★	★
Treatment	★	★★	★★★
Cooling by evaporation	★	★★★	★★
Shadowing	★	★★	★★★

The above options (Table 2) can be used for both new urban areas and projects and maintaining and enhancing the vegetation available in one area. They can be very useful principles for analyzing the existing green matrix in cities and to understand how resilient the urban green infrastructure matrix is, to different types of climate change. By measuring and assessing the resilience of

city green matrixes, principles for enhancing the degree of resilience can be achieved.

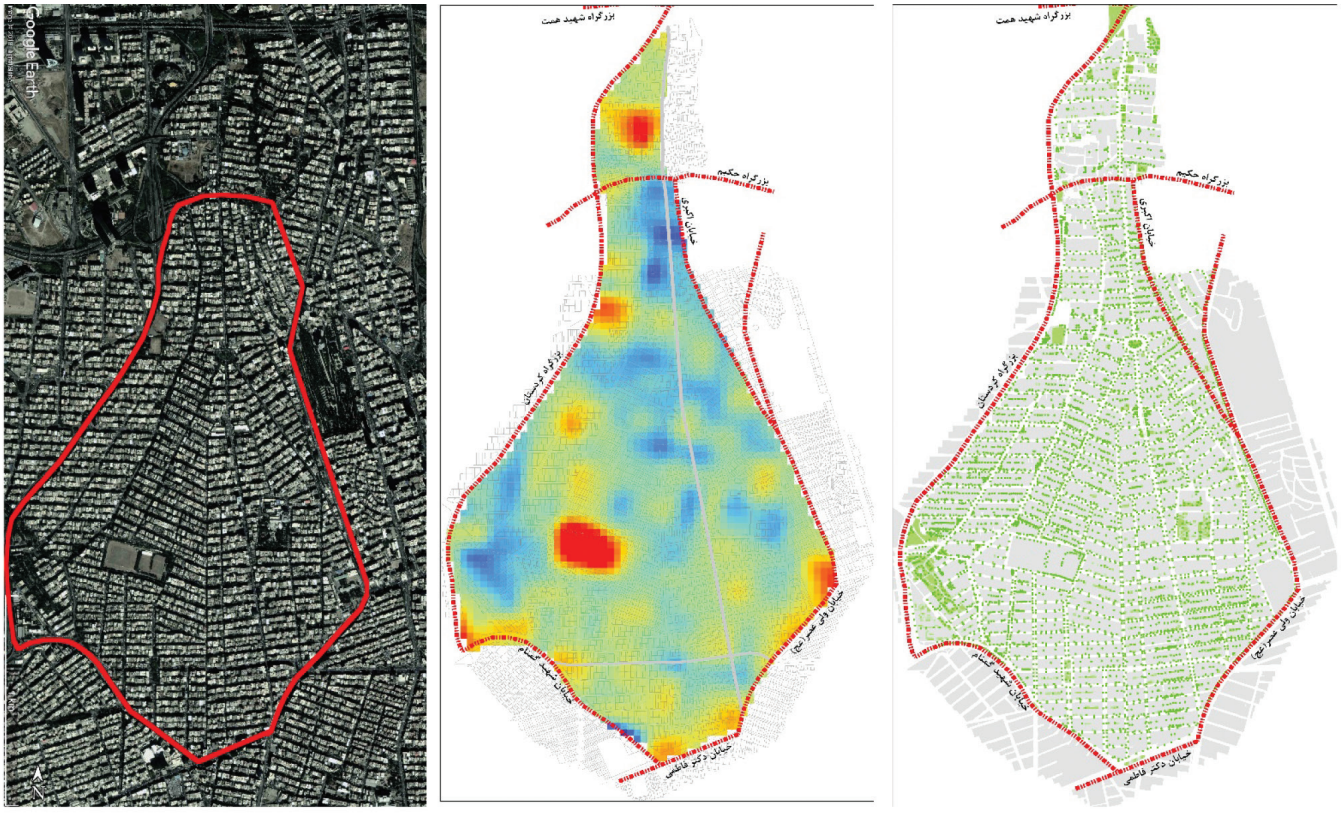
For example, the wider green patches are, the more their resilience will be; and the more natural and artificial corridors are stretched and connected, the more resiliency is guaranteed. These facts can even be used to do a comparison of the degree of climate resiliency between two cities that have been affected by the same climate change conditions. These facts will be more developed later on in this paper.

By reviewing the related literature on urban green infrastructure and their role on adapting to climate change in cities and enhancing climate resiliency, three important strategic principles were developed in order to enhance the existing UGI and to introduce climate resilient green spaces for future climate challenges in countries with increasing drought, water shortages, low precipitation, increasing heat in summers and air pollution in the recent years, which are presented in Figure 6.

A Case Study: Yousef Abad Neighbourhood in Tehran-Iran

Iran is also a country with the main climate change challenges such as drought, extreme heat, reduction in precipitation and water shortage. Here, Yousef Abad, a neighbourhood in Tehran, the capital city of Iran, has been selected for modelling the strategic principles mentioned above. The tools used here, to model the Climate Adaptation Strategies using Urban Green Infrastructure, are aerial photos and GIS maps.

First a recent aerial photo of the area, thermal map and the existing UGI map of the area are presented to display the amount, locations and types of green spaces and on the whole the green infrastructure in the area (Figure 7). There's limited amount of UGI on the neighbourhood, the areas which are coloured in red are the areas with high temperature; therefore it can be proved here that wherever there's no green space, the temperature is higher. This is also a proof



Yousef Abad aerial photo | Yousef Abad thermal map | Existing Plants Map

Figure 7: Yousef Abad's aerial photo, thermal map and the existing plantation map are presented here as tools for implementing the first step of the first strategy which is preservation and enhancement of existing vegetation, scale: 1/9000.

that green spaces and elements have an important role in decreasing the temperature. Also a survey on the plants type and their health conditions was done. Plants which did not have any resilience to the existing climate conditions were recognized, also plants that were valuable based on their resilience potentials but were in bad health conditions, were detected (Table 3). Based on the analysis, a table of suggested plants with high resilience to climate change were introduced for this neighbourhood. It is clear that these plants could also be used in other parts of Tehran and even in other cities of Iran with the same climate conditions (Table 4). Up to here the first and second strategy as seen in Figure 4 have been modelled. In Figure 8 existing and suggested green patches, corridors and matrix based on the science of landscape ecology have been displayed.

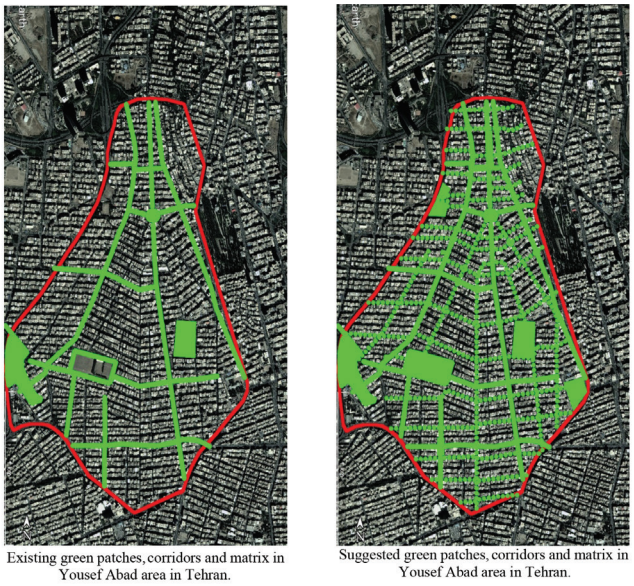
Table 3: Existing plant types and their climate resilience potentials

Plant's scientific name	*Number of plants*	*The amount of shadow*	*The amount resilience to air pollution*	*Irrigation needs*	*Health condition*
Platanus spp. (*Platanus*) orientalis)	A lot	Very little	Resilient	A lot	Unhealthy
Morus spp. (*Morus alba*)	A lot	A lot	Non-resilient	A lot	Healthy
Ailantus altissima	Almost limited	Very little	Resilient	Very little	Healthy
Cercis siliquastrum	Almost limited	Very little	Resilient	Very little	Healthy
Robinia pseudacacia	Almost limited	A lot	Resilient	Very little	Healthy
Ulmus carpinifolia	Almost limited	A lot	Non-resilient	Very little	Unhealthy
Pinus eldarica	Almost limited	A lot	Resilient	Very little	Unhealthy
Cupressus sempervirens	Almost limited	Very little	Resilient	Very little	Healthy
Fraxinus exelsior	Almost limited	A lot	Non-resilient	Very little	Healthy
Ficus carica	Almost limited	Very little	Non-resilient	A lot	Healthy
Poplus deltoides	Very few	A lot	Non-resilient	A lot	Healthy

Table 4: Suggested plant types in Yousef Abad area with the aim of increasing climate resilience

Plant's scientific name	*High shadowing*	*Resilient to air pollution*	*Resilient to drought*
Ailanthus allissima		★	
Albizzia julibrissin		★	
Celis avstruliss		★	
Robinia pseudoacacia	★	★	
Fraxinus excelsior	★		★
Ligustrum vulgare			★
Cupressus sempervirens	★		★
Pinus longifolia Roxb	★		
Eleagnus angustifolia			★
Gleditsa triacanthos	★		★
Quercus rubra	★		★
Betula verrucosa			★
Salix alba	★		★
Melia azedarach	★		
Pyracantha sp.	★	★	★
Crataegus sp.	★	★	★
Lonicera sp.	★		★

This method could help analyze the situation of existing UGI based on their location and new locations can be suggested for new or existing UGI in the area based on the principles derived from landscape ecology in Figure 8.



Existing green patches, corridors and matrix in Yousef Abad area in Tehran.

Suggested green patches, corridors and matrix in Yousef Abad area in Tehran.

Figure 8: Existing and suggested green patches, corridors and matrix based on the science of landscape ecology (green patches, corridors & Matrix)

Findings

1. As shown in the previous section, the first strategy is mostly for analyzing the existing situation, location, quality and quantity of the green infrastructure in a city or neighbourhood scale.
2. After doing a thorough study on the UGI existing situation, climate resiliency can be enhanced by introducing "climate tolerant plants", whether drought tolerant or any kind of tolerance related to the climate challenge that a city is facing. 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.
3. By using Forman and Gordon's landscape ecology 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.
4. Another finding here is having presented 'strategic principles' to reach a better climate resilience condition through urban green infrastructure.
5. The combination of Forman and Gordon's rules with UGI's role on climate resiliency, can be developed more into principles for analyzing climate resilience situation in a city and for even comparing two or more cities' resilience condition. These principles are better defined in Figure 9.
6. One of the most important points here is that the strategies and principles that were mentioned earlier and 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.
7. Based on Figure 9 and the analysis done on Figure 8, there are very limited number of green patches in the area and the green corridors are also disconnected in many parts of the neighbourhood; therefore there is no connected and well-shaped matrix. Because wider and more connected patches along with more stretched green corridors are more resilient, more patches were suggested in the available locations and corridors were connected. This leads to a more comprehensive matrix which guarantees more climate resiliency to air pollution, drought, water shortage etc.

Conclusion

The concept of climate resilience is a relatively new term introduced in conjunction with a variety of other types of resilience. It means the capacity of ecological systems to absorb distractions and to maintain the feedback, processes and the inherent structures of the system. In other words, the severity of the damage of the system can be absorbed before it transforms the structure into a different structure by changing the variables and processes that control its behaviour.

By reviewing the literature on climate resiliency and its various dimensions, the importance of urban green

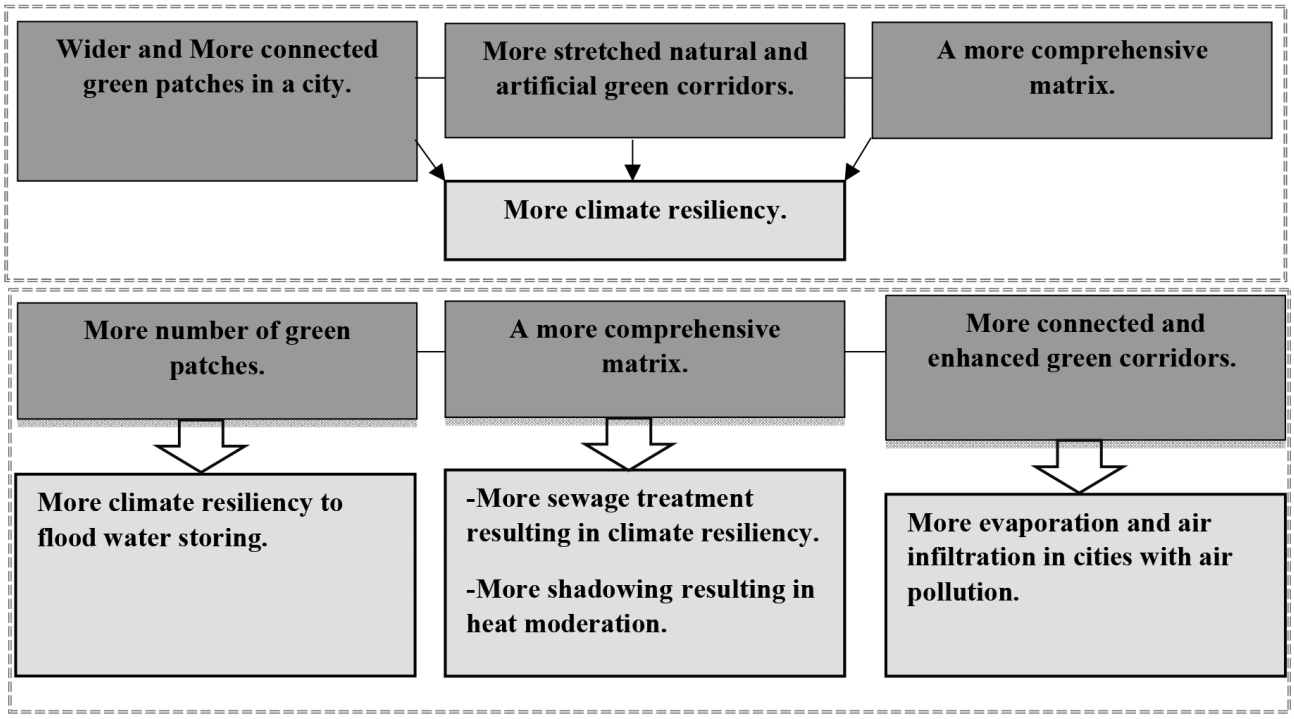


Figure 9: Principles for analyzing UGI conditions based on their climate resilience role in a city through the language of landscape ecology (Patches, corridors and matrixes).

infrastructure as one of the most important strategies for adapting to climate change, factors influencing climate resiliency and the importance of creating and maintaining and enhancing them, is raised.

Basically, climate change that has a negative impact on urban-scale climate resilience is beyond the scope of urban planning and decision-making, but adverse climatic changes lead to a reduction in environmental resilience. Instead, there are variables for controlling and intervening in the environment such as the strategic principles of adaptation to climate change through urban green infrastructures which can be effective on climate resiliency for the reasons mentioned before.

It is clear that climate changes are hard to control since it requires a wide comprehensive global network of decision making. One way to somehow control and reduce these negative impacts is by meddling with the green infrastructure in the cities by analyzing their existing conditions and evaluating their resilience potentials based on the way they are located and connected on one hand and the type of species they are composed of on the other hand and to later on, make suggestions for each city based on these qualities and quantities to enhance their resilience conditions. Also these principles can also be used for new projects and for making decisions about the green spaces and their species beforehand.

By adopting proper quality, quantity, principles and strategies in the field of urban green infrastructures, urban climate resiliency can be affected and strengthened. This area is subject to the will of urban planners and designers. Therefore, climate change and its negative effects on urban climate resiliency can be prevented.

As a result, principles and frameworks based on the quality and quantity of urban green infrastructure in cities can be introduced. They can directly affect and mitigate climate changes.

By studying urban green infrastructure strategies to explain climate resiliency approaches, several important strategic principles have been proposed, including the use of landscape ecology and classification of green infrastructure into patch, corridor and general form of the matrix in order to examine the current status of green infrastructure in one or more neighbourhoods in cities. This helps with providing approaches to analyze the existing UGI based on their climate resiliency.

Considering the strategies of adaptation to the above-mentioned climate changes, studying status of vegetation in cities is the first step of analyzing the current situation using the landscape ecology and the concepts of patch, corridor and matrix as the analytical language of this science. It can provide a better analysis of the existing urban green infrastructure, and even provide a method for measuring and evaluating this infrastructure to

determine their impact on climate change resilience in cities. This method can be developed more into another paper or research project to derive precise measuring tools and techniques for studying patches, corridors and matrixes in a city.

Providing a list of drought-tolerant plants which are resistant to water shortage and purifying and refining air quality, can also lead to a resilient strategic principle of planting on the street, roof, facade, and so on. According to the studies done for this paper, this step has not been done officially as of today. This could also be a step to further the studies on UGI and urban resilience.

It seems that studies in the areas mentioned are less oriented towards improving the situation of the neighbourhoods. That's why the neighbourhood scale was modelled here. In addition, standards, indicators and components for measuring resilience in this scale have not been properly elaborated. This could also be the third point made by this paper to suggest further studies on the issue.

Analysis of the current situation, quantity and quality of vegetation, the way green infrastructure is located in the neighbourhood, and the standards for achieving climate resiliency through this infrastructure can be part of the existing shortcomings in this area of study. Urban neighbourhoods are considered as the best scale for applying new concepts of urban design and planning. Therefore doing a study on the neighbourhood scale is also another suggestion for further reading. And finally, using nature and its natural capabilities is the best way to save the planet from the issues it is facing due to human action.

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