Assessing the effects of population growth and climate change on sustainable blue-green infrastructure (Case study – Qazvin)

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ABSTRACT

Over the past century, population growth and climate change have affected most cities in developing countries, being damaged extensively at different scales. For instance, in Iran, the historical sustainable blue-green infrastructure (BGI) is under pressing pressure. However, sustainable BGI could support the environmental, social, and economic sustainability and mitigate as well as adapt to climate change. Qazvin, the historical Persian garden city in the middle of Iran, is a valuable sample of sustainable adaptation to drought and water shortage. Due to the urban development process, population growth, and climate change during the last century, Qazvin has lost a significant part of its historical blue-green infrastructure. This paper aims to assess the effects of population growth and climate change on sustainable BGI in Qazvin and offer appropriate solutions for conserving and rehabilitating sustainable BGI. The research methodology is the case study method. Hence, the principles of environmental, social, and economic sustainability dimensions in the blue-green infrastructure are identified. Data related to population growth, climate change, and urban development in Qazvin are collected, and the effects of these factors on sustainable BGI are analyzed. Finally, the proposed mechanism implementing the sustainable BGI adapted to climate change and urban development has been introduced.

Keywords: *blue-green infrastructure, sustainability, Population growth, climate change, urban development*

INTRODUCTION

Nowadays, the world faces three main problems, including increasing food demand, population growth, and climate change (Beatly 2000). The world's population is reaching unsustainable levels (UN, 2017), resulting in cities' considerable growth and creating sustainability challenges. FAO and Matuschke independently mentioned that a high rate of urbanization in developing countries could increase the number of underprivileged inhabitants and food security threats (FAO 2010 & Matuschke 2009). Urbanization can be considered the most extreme form of land use, decreasing the environment's capacity for providing ecosystem services and biodiversity (Wu, 2010). Growing demands for energy, water, education, healthcare, housing, transport, and public service are testing

urban infrastructure limits (Estevez et al. 2016). Dutt et al. (2003), Yuen and Kumssa (2011) noted that cities in Asia have the most significant challenge with three issues mentioned above, in comparison to other cities in developed countries (Yuen and Kumssa 2011). For example, as a developing country in Asia, Iran has faced a wide range of environmental issues resulting from climate change and population growth. The increase in the average temperature, the urban heat island effect, the decrease in precipitation, drought, and dust particles are some of the environmental problems. Hence, due to the urban development process, population growth, reduction in respiration, and increasing global warming, Persian garden cities such as Qazvin have seen damages. In particular, the loss of urban blue-green infrastructure (BGI) due to urbanization processes decreases the physical and mental health of urban residents, for example, due to intensification of the urban heat island effect (Lafortezza et al. 2009), noise pollution (Gidlöf-Gunnarsson and Öhrström 2007), and loss of spaces promoting public mental health (Grahn and Stigsdotter 2010). Many studies have argued that the urbanization process affects not only the spatial pattern of urban blue-green infrastructure (Zhou et al., 2014) but also the urban green space (Li et al. 2013; Wu et al. 2011), which, in turn, influences its ecosystem services such as mitigating urban heat island (Kong et al. 2014; Li et al. 2011).

Persian garden cities such as Qazvin, with a history of seven thousand years in Iran, could ensure environmental, economic, and social sustainability. However, sustainability in Qazvin relies on sustainable blue-green infrastructure shaped for thousands of years.

Blue-green infrastructure is a strategic, multi-functional network of public green spaces and routes, rivers, water canals, lakes, landscapes, biodiversity, and heritage (LDA Design Consultant, 2011). Sustainable blue-green infrastructure includes techniques and technologies that use natural systems or engineered systems that mimic natural processes to enhance the built and natural environment, particularly within stormwater management (center for neighborhood technology & American rivers, 2010). It ensures efficient and sustainable land use by integrating and interacting functions or activities on the same land piece.

Blue-green infrastructure in Persian garden cities is a combination of gardens, farms, urban agriculture, seasonal rivers, and water canals. The relationship between urban agriculture with maintaining urban runoff, food security, urban heat island effect, climate change, low quality of life, social isolation, and crime prevention has been identified (Mazereeuw 2005). Urban agriculture can ensure environmental, economic, and social sustainability. It also provides local employment and income (World tourism organization, 2002). Agriculture in urban areas creates the opportunity that the food chain associated with the production-consumption becomes limited. Organic household waste can be used and turned into fertilizer and used in farms and gardens. This process brings ecological and economic savings (Dehqan 2002). In societies where obesity is a health issue, urban gardens allow residents to increase their physical activity through gardening. Hence, as a part of the blue-green infrastructure, urban agriculture can play a crucial role in taking steps toward future sustainable cities.

Finally, sustainable blue-green infrastructure has a key role in making cities inclusive, safe, resilient, and sustainable, taking urgent action to combat climate change and its impacts, sustainably managing forests, combating desertification, halting, reversing land degradation, and halting biodiversity loss. Consequently, we can take steps toward the United Nations' sustainable development goals (SDGs).

METHOD

In this paper, the research method is a case study. The main aim is to analyze the impacts of urban development, population growth, and climate change on Qazvin's sustainable blue-green infrastructure. Qazvin's historical blue-green infrastructure is chosen as the case study, and then data related to urban development, population growth, and climate change in Qazvin were collected. After analyzing the data, the effects of population growth and climate change on Qazvin's sustainable blue-green infrastructure were assessed. The results can lead to the proposed mechanism, which should pave the way toward three of seventeen sustainable development goals (SDGs), including sustainable cities, climate action, and life on land.

Case Study

Qazvin is one of Iran's historical cities, and its history returns to the second and third millennium BC. Five thousand years ago, Qazvin was an inhabited region, and the discoveries obtained from archaeological excavations have proved the existence of a rich civilization in the city (Varjavand, 1970). The blue-green infrastructure in Qazvin is the network of natural and semi-natural features, including gardens, farms, seasonal rivers, and water canals that intersperse and connect different parts of the city (Figure 1).

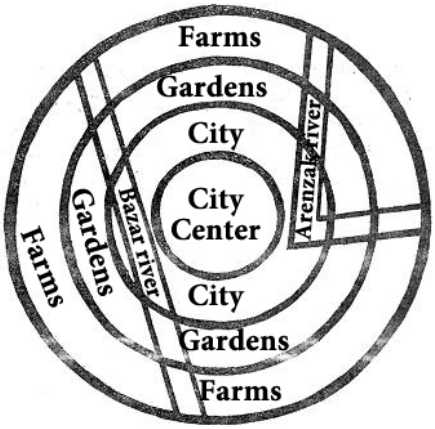

Figure 1: Map of Qazvin city in the 14th century (Qazvini, 1994).

This network has the potential to deliver a wide range of benefits, from providing a sustainable environment, economy, and society to mitigating and adapting the effects of climate change. The green infrastructure includes three scales of urban gardens and farms in the Persian garden city (Qazvin), including the suburban, urban, and private gardens.

1. The suburban gardens

The suburban gardens refer to gardens and farms that are in the suburban areas and outside the city. These gardens have a self-organizing form and fractal pattern. The domain of the function embraces areas outside of the town. The suburban gardens can mitigate the harsh climate's effects and create a moderate microclimate within extreme climatic conditions. In other words, by reducing the temperature, increasing humidity, saving water, and mitigating unfavorable winds, the suburban gardens have made urban life possible within the city for thousands of years.

2. The urban gardens

Urban gardens have existed for many years ago in this city. The urban gardens are divided into two categories. The first category is only for food production. The second group is the governmental

promenades and public gardens. Furthermore, the urban gardens act as green infrastructure in the city, merged with rivers and water canals. As a result, the network of gardens, farms, rivers, and water canals manages the flash floods by distributing floodwater in urban gardens and farms, uses waterflood to irrigate gardens and farms, and reduces the urban heat effect island effect and temperature in the city.

Moreover, urban gardens have played the role of the aquifer to supply groundwater resources. The network of blue-green infrastructure in the urban scale has adapted and mitigated the extreme weather condition, applying "green engineering" techniques to increase stormwater infiltration in urban areas for runoff reduction and flood mitigation. In other words, the blue-green infrastructure works similar to veins in the human body, and distributing flood water to each scale of gardens and farm, allow water to penetrate the soil, enriching underground water resources. They have circulated water and green spaces in the city.

3. The private gardens

Private gardens include gardens with a micro-scale and personal property ranging from a single tree to small private gardens. The domain of its function embraces households and residential areas in the city.

The mentioned three scales address some of the environmental, social, and economic issues, and then the network of the blue-green infrastructure provides the following ecological, social, and economic sustainability:

- Environmental sustainability

The blue-green infrastructure is a tool to protect the advantages and services that the environment provides. The urban gardens and farms producing different products have a substantial role in food security. Thus, Qazvin gets most of the citizens' food from the green infrastructure. The urban gardens create a microclimate by increasing moisture, reducing the temperature, providing a pleasant smell in the city, breaking wind speed, buffering solar radiation, and creating shade. They also improve air quality by removing pollutants in the air, such as chemicals and allergens like pollen. Noise pollution in urban areas is usually prevalent due to increased density, heavy traffic, and many hard surfaces. The urban gardens are efficient in reducing noise pollution. The blue infrastructure helps collect floodwater, recharge water tables, and reduce erosion by slowing down runoff. The rivers transport the water across the BGI, allowing gardens and farms to deplete this water. Restoration of biodiversity is another significant environmental benefit of the BGI. Besides, they help to protect endangered species, including animals and plants.

- Economic sustainability

The BGI has several economic benefits to society, promoting economic development and tourism. The BGI attracts businesses and residents, and as a result, it is a catalyst for business development and promotion of urban life quality. By studying the BGI in Qazvin, it is found that it improves residential and commercial spaces' quality and increases properties' value. The urban gardens and farms also create local employment and income, and they are economic potential to develop local economic activities. Food production in the urban spaces creates an opportunity that the food chain associated with the production-consumption process becomes limited. Organic household waste is turned into fertilizer and used in gardens and fields. This process brings environmental and economic savings. Besides, due to three factors, including experience (rural migrants have experience in agriculture), requirements (a large number of unemployed workers), and opportunities (marginal agricultural areas and vacant urban lands), the BGI in Qazvin provides acceptable reasons for the development of urban agriculture and preservation of the sustainable blue-green infrastructure.

- Social sustainability

The social aspect of the BGI in Qazvin has several factors mentioned in the following:

1. Increasing physical activity: In Qazvin, where obesity is a problem, the BGI provides an opportunity for residents to improve their physical activities through gardening, walking, doing exercise, and so on.
2. Health (garden therapy): Looking at nature scenes has positive effects, relieving pressure, and stress. A variety of sounds, smells, and colors significantly impact people's health and welfare. Access to organic and fresh food is also one of the essential issues; urban agriculture emphasizes the existence and availability of food. Also, they reduce air pollution and reduce the urban heat island effect. Both factors have significant impacts on physical health. The studies show the relationship between psychological stress and the urban landscape characteristics.
3. Increasing security: Crime rate reduction has been observed in the area covered by the BGI in Qazvin. The citizens spending their time in urban gardens are reluctant to commit the crime. The urban gardens also provide a safe environment for the residents, especially children and women.
4. Greenspace and aesthetic values: The network of gardens and rivers promotes aesthetic values and provides more green spaces for residents.

Data analysis

In this section, three factors of population growth (Figure 2), mean temperature (Figure 3), and annual precipitation (Figure 4) in Qazvin city are analyzed. The effects of these factors are assessed in the sustainable blue-green infrastructure (Figure 6).

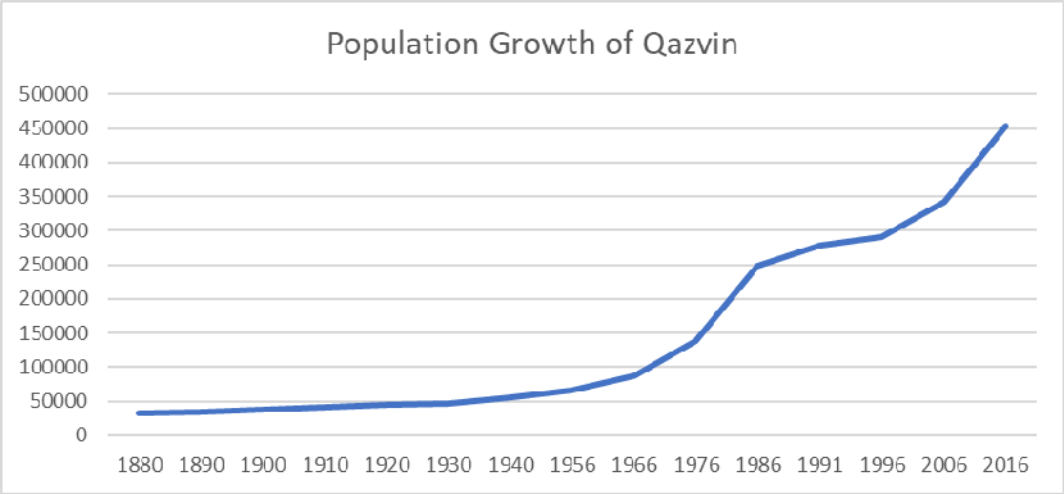

Figure 2: The population growth of Qazvin from 1880 to 2016 (https://fava.qazvin.ir/en/58)

According to the above line graph, Qazvin's population increased steadily by 1956. After that, considerable growth can be seen. It can also be anticipated that the upward trend continues.

In the next step, climate change factors, including mean temperature and annual precipitation, should be considered in Qazvin.

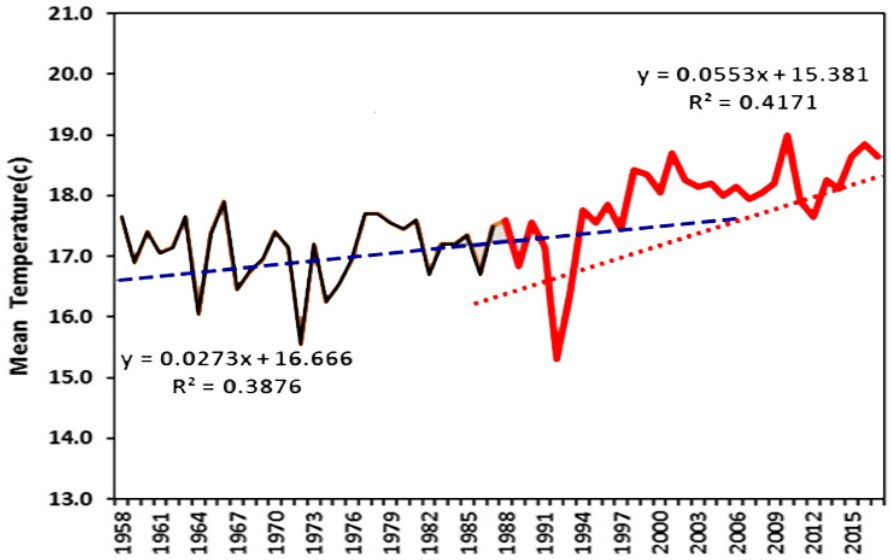

Figure 3: Mean temperature from 1958 to 2016 in Qazvin (https://data.irimo.ir)

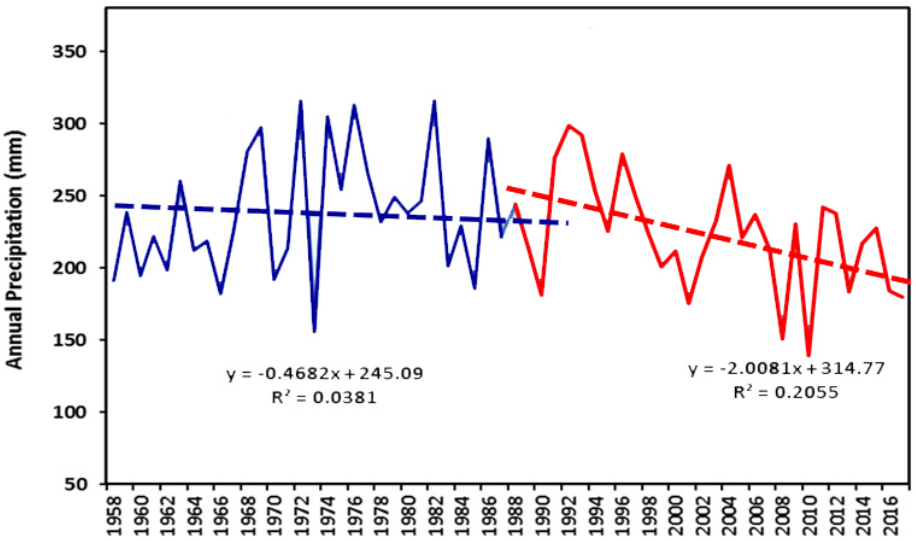

Figure 4: Annual precipitation from 1958 to 2016 in Qazvin (https://data.irimo.ir)

Regarding the upward trend in mean temperature and the downward trend in annual participation, it is evident that the city is under climatic pressure, especially for the last 50 years. In the following map, the impacts of population growth and climate change on the three scales can be seen.

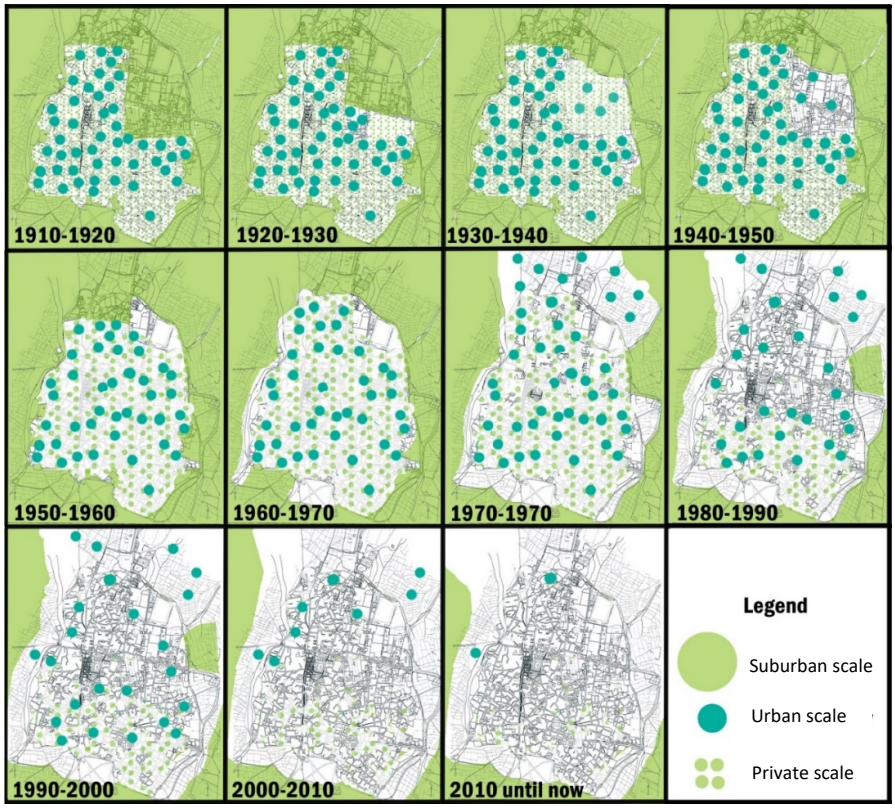

Figure 5: The urban development process from 1910 to 2010 in Qazvin

The urban development process in Qazvin shows that the rapid growth of urbanization reduces suburban gardens' area dramatically. By analyzing the reduced green infrastructure, the following diagram is obtained (Figure 6).

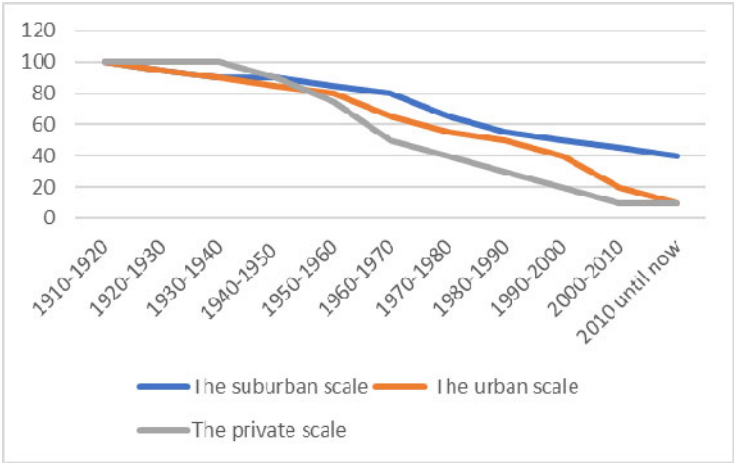

Figure 6: The analysis of the areas of three scales of green infrastructure from 1910 to 2010 in Qazvin

The graph illustrates that despite the reduction in all categories of gardens, urban agriculture in the countryside has less reduction. The following maps show the remaining parts of the blue-green infrastructure (Figure 7)(Figure 8).

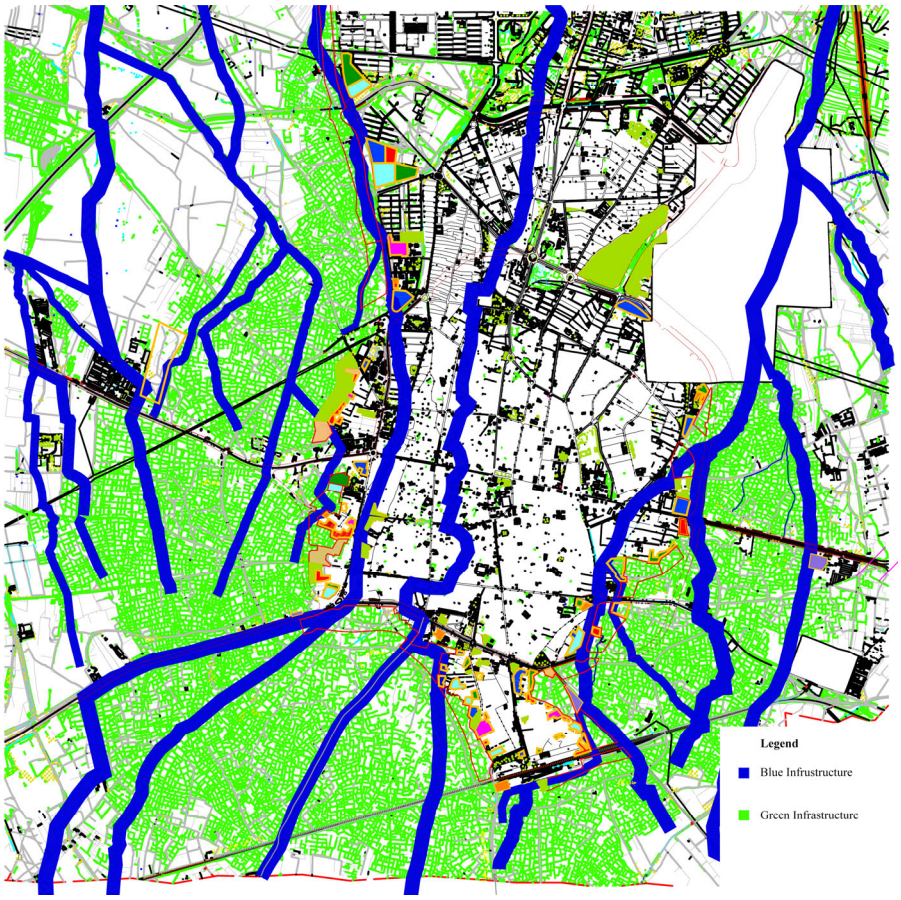

Figure 7: The remaining parts of the blue-green infrastructure

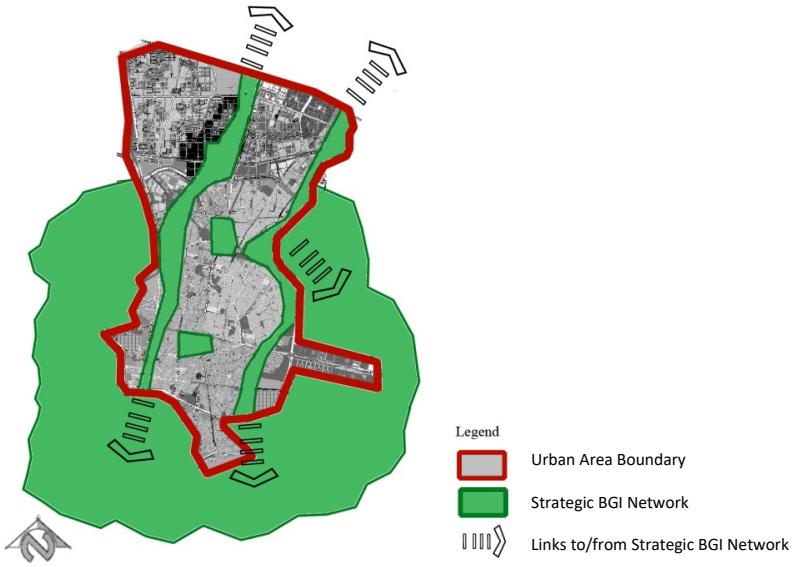

Figure 8: The strategic blue-green infrastructure network in Qazvin

RESULTS AND DISCUSSION

The analysis shows that both population growth and climate change damaged the blue-green infrastructure in Qazvin. The combined blue and green infrastructure areas in 1910 were 3000 hectares, and now it covers only 2300 hectares. Inhabitants can get services from the blue-green infrastructure if the BGI works appropriately, and there is capable of the infrastructure's working. The reduction in the area of the BGI affects the correct functioning of the target BGI, having adverse effects that are relevant to the general function of the BGI in sustainability and three dimensions of sustainability in Qazvin. Thus, the current BGI faces some strengths, opportunities, and threats, as shown in the following table (Table 1).

Urban Sustainability	Strength	Opportunity	Threat
Environmental Sustainability	-Irrigation by floodwater -Irrigation in the cold seasons to eliminate parasites (with freezing soil) -Defense against the hot wind blowing from the desert -Moderating dry and hot climate by increasing humidity and decreasing temperature -Control the wind speed -Absorb solar radiation - Implementing a variety of species which don't need so much water -The Seasonal rivers are employed in the irrigation of gardens	-Conservation of biodiversity - Improving climate condition - Decreasing the urban heat island effect -Protection of endangered or scarce species (including plants and animals) - Protection of soil against erosion - Absorb dust particles and emissions from air pollution - Reduce noise pollution in urban areas - Promotion of biodiversity - Reducing garbage through organic fertilizers	- Water shortage in recent years - Damage gardens while developing the city
Economic Sustainability	-Flood management -Producing food	-Developing ecotourism -Providing related jobs -Organic household waste can be used in gardens - Creating farming markets -Reducing the transportation of agricultural products	- Increasing the cost of labors, manures, pesticides, etc. -The lower rate of agricultural productivity in traditional agriculture in comparison to industrial agriculture - Rising cost of houses, which persuades farmers to transform their gardens into houses -Decreasing income derived from conventional agriculture
Social Sustainability	-Creating public spaces -Providing pleasant scenes to attract people - Traditional festivals - Traditional management	-Providing a safe urban space with private management -Increasing the quality of life in the residential area - Preventing crime -Increasing physical activity - Providing garden therapy - Increasing security -Creating the green space -Providing aesthetic values	- decrease social safety in damaged parts of the BGI

Table 1: The strengths, opportunities, and threats of the blue-green infrastructure in the current situation

The blue-green infrastructure needs to be correctly managed to maintain the sustainable network's strengths, respect the requirements, give an adequate response to opportunities, and find solutions for threats. Hence, the sustainable blue-green infrastructure should be correctly protected because the essential functions of the BGI as it is an appropriate level of connectivity among natural elements should be maintained and taken into account. Finally, in the case where properties and functions of the BGI have been lost, due to population growth and climate change, they should be restored and rehabilitated.

PROPOSED MECHANISM

For meeting environmental, social, and economic objectives while delivering sustainable development goals of the UN, we should take a holistic approach to preserve and restore the sustainable blue-green infrastructure. Three mechanisms can be proposed as a feasible strategy (Table 2).

Guidelines	Proposed Mechanism
Environmental	Absorb Carbon dioxide Improve air quality Add more recreational space Improve the efficiency of land use Improve physical and mental health Flood management Water and soil source protection Save groundwater resources Improve watershed health Preserve and restore wildlife habitat
Economic	Maintain historical blue-green infrastructure Increase land values Improve economic development Reduce energy consumption and costs Increase life-cycle cost savings
Social	Establish green spaces for fun and enjoy Provide a safe environment for all social groups Educate the public about the importance of maintaining the BGI

Table 2: The proposed environmental, economic, and social mechanism

The proposed strategy requires initial planning and policymaking, requiring investment, partnership, and cooperation. It needs to draw the attention and assistance of various groups, such as:

- Eco-friendly groups
- Landowners and agricultural, municipal managers
- Municipality
- Active Companies in this field
- Volunteer organizations
- The relevant government planning system and grant funds

CONCLUSION

This research argued that both population growth and climate change caused significant damage to Qazvin's sustainable blue-green infrastructure, which has a wide range of environmental, social, and economic sustainability functions. Considering the destruction of the blue-green infrastructure in Qazvin in three categories including suburban, urban and private gardens, shows that along with the increasing trend of the population growth and climate change, private urban gardens have been faced a reduction of 90% and only about half of the suburban gardens have remained. Identifying strengths, opportunities, and threats faced with the blue-green infrastructure's current situation show the necessity of introducing a proposed mechanism for protecting and restoring the blue-green infrastructure. Aaccording to data analysis, urban development, population growth, and climate change will continue. Thus, the proposed mechanism plays a vital role in taking steps toward the future sustainable city. Consequently, the sustainable blue-green infrastructure should be rehabilitated and ensure three sustainable development goals, including sustainable cities, climate action, and life on land. Besides, Qazvin will be adapted to population growth and climate change effects, including water shortage, increasing temperature, and natural hazards.

Finally, as the research data process occurred before the start of the pandemic of COVID-19, the pandemic did not affect the research.

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