Recent Researches in Science and Landscape Management

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Edited by

Recep Efe, Murat Zencirkiran
and İsa Curebal

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PREFACE

This book, "*Recent Researches in Science and Landscape Management*" has 50 Chapters including aspects of landscape architecture, urban landscape, green spaces, recreation, ecology, cultural landscape, spatial planning, plants for landscaping, play grounds, agriculture, plant diseases, changing leaf micromorphological characters, architecture, animal husbandry and bioclimatic comfort.

Contributions in each chapter are prepared by experts in the respective fields and mirror the advancement in the approach. This book contains important future tasks of the particular fields and supplies extensive bibliographies at the end of each chapter, as well as tables and figures that illustrate the research findings. All these make this book highly useful and a must read for students, researchers and professionals in landscape architecture, ecology, crop protection, plants for landscaping, agriculture, animal husbandry, ecology and environmental sciences.

We would like to express our gratitude to all contributors for bearing with us as the volume has taken time to come to fruition

We particularly wish to express our thanks to the team at Cambridge Scholars Publishing for preparing the book for publication.

The Editors

CHAPTER 1

A STUDY OF PERSIAN GARDENS BASED ON ISLAMIC GARDEN DESIGN PRINCIPLES: BAGH-E FIN AND BAGH-E DOLATABAD

PARISA GÖKER

Introduction

Islam's birth place is Saudi Arabia and it started to spread swiftly from Palestine to Iraq, Syria, Mesopotamia, Iran**,** Turkistan and a section of Punjab till Northern Africa and Spain and this in turn led to the birth of Islamic culture. Islamic culture and art, in addition to belonging to a certain country or society, transformed into an independent art that improved with the effect of culture and art perspectives of different civilizations and had joined characteristics as well as regional characteristics due to the impact of the religion.

Islamic gardens have features reminiscent of the paradise phenomenon classically as impeccable relaxation and contemplation sites. As Islamic gardens are generally perceived in scorching and dry climate areas water and shadows occur as the principal elements of these gardens. Garden areas were turned into sites suitable for irrigation by benefiting from water sources or streams for providing water for vegetation. It was required that the ground was somewhat sloped to implement these methods and to allow the channel to flow. The channel network crossing one another in straight lines generated the basics of the geometric garden design. The marks of garden art in Persia can be traced back to very early ages. Iran before Islam developed with the effect of Buddha in the east and Christians in the west and central Iran was under the effect of the Zarathustra religion. Based on Zarathustra faith, which was the most powerful and influential religion during that era, natural components such as soil, water, air and fire were vital. Zarathustra believed that every person who planted seeds was walking on God's (Mezdisna) path. Mezdisna meant God in the

Zarathustra religion. Faiths changed after Islam yet the love of nature has persisted in Iran until today. Planting trees, garden construction and the love of flowers were based on this old philosophy. Therefore, splendid palaces and gardens were built in Iran during historical ages by emperors. There are numerous palaces and gardens located in Isfahan, Shiraz, Yazd, Kashan and Tehran and at the seashore of the Caspian Sea (Kluckert, 2000).

In this research, in addition to putting forward the Islam garden art perspective and design components, Bagh-e Dolatabad in Yazd City and Bagh-e Fin located in Kashan City were assessed. According to the derived data, the plan diagram, site organization and structural elements and plantation materials situated in gardens were examined. Moreover, the attributes, features and variations of the gardens reviewed in the study scoped in various cultures and geographical locations were uncovered.

Islamic Gardens

Islamic civilization caused substantial changes in the landscape that it occupied. With the ingenious procuration and transportation of water, the withered lands of the middle-east and northern Africa became vivacious owing to man-made green oases that not only changed the economy with their agricultural products but also became a strong means of cultural statement. The techniques applied to affect this change stemmed from the ancient Persians and Romans. However, Muslim communities applied them more extensively due to complicated purposes that had something to do with the system of land ownership and labour, inheritance codes, taxation, urban growth and a country life that was idealized (Ruggle, 2007).

The recently conquered Islamic world was mainly a parched landscape (the Arabian Peninsula, Syria, Jordan, the Anatolia Plateau, and most of Iran excluding the coast North Africa) where it rains seasonally yet not systematically even during the assumed rainy season. Islamic gardens were constructed during different complicated layers of time and compacted factors, which implies the “notion of unity in diversity, and they were multi-layered throughout centuries with supposedly insignificant changes”, as purported by Attilio Petruciolli.

The garden art developed under the influence of Islam and Christianity fundamentally for approximately a thousand years starting from the 7th century BC when Arabs started to spread the Islam religion and culture. However, Islam garden art has marked garden cognizance in all Mediterranean countries especially in Europe until the Renascence (13th

and 14th centuries BC). In this context, the common features existing in the gardens in Spain, Iran and India whose living examples are taken as fundamental, are:

- The most important common feature is the description of Heaven in the garden which does not exist in the world and is idealized, holy and admired;
- There are structural groups constructed as mansions, pavilions, places and such in all gardens;
- The backyards and gardens in Islamic culture are enclosed by walls or porches;
- The use of water as stagnant, in embellished pools, sprinklers and cascaded canals to generate intense sound effects has been a determinant attribute;
- It is seen that Islamic gardens have a formal and symmetrical structure in general. The geometrical formal order in Islamic gardens in Spain manifests itself in a four-sectioned system (chahar bagh) seen mostly in Iranian and Indian gardens;
- Trees planted in a straight line in Islamic gardens also aim to emphasize the existing geometry further, hence, the use of plant material generally follows the lines of garden walls or pathways.

These common features have been shaped in integration with the unique values of each geographical location and culture. The garden examples which have survived until the present in Spain, Iran and India turn out to be the proof showing the design characteristics in Islamic gardens.

As far as the above given discussions are concerned, the attributes of Iranian gardens can be classified as follows:

- A garden is a description of Heaven (considering the Iranian view about Heaven and its role for the emergence of Iranian gardens);
- The function of land and beds is crucial considering the topography, fertility and position of the garden in terms of function and type;
- Running water is the principal element in Iranian garden construction. This is crucial in terms of three aspects: water supplies, the irrigation type of the garden and the use of water as decoration (aesthetically);
- Building a green belt and its favourable effects against the arid and desert climate of Iran have increased the significance of garden

construction;
- Focusing on the main axis and geometry and the application of square and rectangular shapes during garden design generate a unique platform.

Water and Garden in Islamic Wilderness Culture

Gardens in ancient Persia were built based on water sources. At the beginning, gardens were cultivated to grow orchard trees for their fruits and shade in addition to crop nutrients. Water was procured from springs and collapsed wells and transported via an underground conduit system network called a "qanat", which emerged in Persia in the 7th century C.E. For the procurement of water from distant sources, a high level of hydraulic modifications and abilities was required. Following the introduction of Islam in Persia during the 8th century C.E., Persians invented the water wheel to raise water for irrigation with the use of rapidly running river water or by using oxen or sometimes ostriches. This is how the ancient gardens of Baghdad and Samarra were constructed. One of the first examples of a desert garden was the garden of Cyrus the Great, the King of Achaemenid (590-530 B.C.E.) in Pasargadae built in 550 B.C.E., at least 1000 years before Islam was introduced (Ansari, 2011).

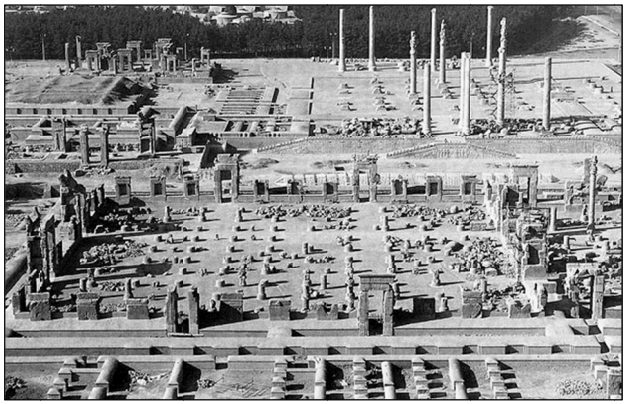

Fig. 1: Water Carrying System (Pasargad, Iran)

The Achaemenids built qanats also by lowering a pivot down to the water table under the mountains to make a tunnel that extended for nearly 80 kms to a wilderness settlement. This was crucial on the high plateau of Iran since there was very little rain and river water and the water table depended on the amount of snow melt. The qanats sent water to a tank

which was somewhat higher than the highest location in the garden. This would be helpful in the irrigation system that was built based on gravity. The water was subsequently used for many purposes; some creeks were very narrow and used for irrigation, some ran underground and were used for the cyclic flooding of buried flower beds and some others were used for cooling the air.

Irrigation was crucial for gardening in the arid climate of North Africa and the Middle East. Excluding the rainy season, water was received from water resource basins, rivers, canals, rainwater cisterns and the water table. It was best if the water source was higher than the destination point, and a surface canal reached a basin on high ground by the palace, where it could be let go when needed, flowing with the effect of gravity into the palace and gardens. If the water source was lower than the field, garden or dwelling which was going to use the water, either a *Noria* (water wheel) or *Shaduf* (pole and lever) was used to bring up the water in the buckets. In some landscapes, on the other hand, a *qanat* (subterranean canal) could drain the lifted water at the mountain base and run it underground for many miles until it reached man-made farms and gardens. The joint confidence in irrigation points to the close relation between garden and farming. Gardens don't survive from the dark ages because of the delicate structure of plant life however the significance of gardening is evident from historical definitions, botanical scientific investigations, agricultural booklets and poetry (Ansari, 2011).

The water was taken from streams and collapsed wells and transported via an underground conduit system network called a "qanat", which emerged in Persia during the 7th century C.E. Receiving water from distant sources necessitated a high level of hydraulic changes and ability. After the introduction of Islam in Persia in the 8th century C.E., the Persians invented the water wheel to lift water for irrigation by using rapidly running river water or oxen or sometimes ostriches. This was how the ancient gardens of Baghdad and Samarra were built.

A qanat is a type of underground irrigation canal extending between an aquifer on the piedmont and a garden situated on a withered plain. Qanat is an Arabic word, however the system is best known in Iran. A water source, such as an actual well, is needed to build a qanat; however it can also be an underground reservoir or a water-bearing geological layer, which can be a damp area in an otherwise withered region. Once this resource is identified, a tunnel is sectioned to the farm or village that needs the water. Shafts are included for three reasons: as an air supply, for eliminating sand and soil and for preventing tunnels from becoming dangerously long. The shafts are not very far apart and as a result, a qanat

seen from the air gives the impression of a long, straight line of holes in the ground—as if the land was going through a bombing raid. The qanat turns to a ditch near its destination typically; in other words, the water is lifted to the surface by letting it get out of the ridge.

Evaluation of Chahar Bagh

The foundation of Persian gardens was set with "Chahar Bagh" which had a four-part formal plan of two channels intersecting one another vertically. The utilization of symmetry in garden designs helped to attain balance in the garden. The components in the garden are positioned on a symmetrical axis or in the centre of the garden. The intermediate point of the symmetrical order is called the "cihannuma" or peak point of the main axis. The symmetrical order is implemented for plant design in the garden also. Trees and bushes are positioned in the vicinity of the hiking areas to highlight the main axis. Seasonal plants are planted within symmetrically designed parquets (Tuna and Göker, 2017).

A Paradise Garden was built in the classic Chahar-bagh design which divided the garden into 4 parts by means of water channels; the 4 water channels were the 4 rivers of paradise as Islam described. The geometrically arranged beds under the flanking pathways consisted of plantations of fruit trees and roses and other flowers and this made irrigation simple and at the same time gave a sensation of walking on a carpet of flowers. Before the birth of Islam, in addition to being affected by geographical conditions, gardens were influenced by people's traditions, rituals and cultural background.

Persian Gardens

The transition of Persian gardens had started more than a millennium prior to the introduction of Islam in Iran and these gardens have always portrayed heavenly architectural gardening organization. The reflection of spirituality on the daily life of people contributed to the creation of even superior scenery during the Islamic period. The earthly paradise concept was the principal notion behind Persian garden design. As the expression implies, these gardens were enclosed (Göker, 2017).

The aim of the garden was to be a site for impeccable rest and leisure such as meetings with friends and in this way it would construct a paradise in the world. The Persian garden tradition and style affected garden design from Spain to India and in other countries. Persian garden styles were based on the Egyptian garden style concept. The factors turning a Persian

garden into a paradise on Earth were microclimatic effects, high-walled structures, shady trees, streams, fountains and pools. Persian gardens consisted of various types of fruit trees and flowers, shrubs, shady plants and such. Islamic cultural values influenced the architectural and geometrical structures of Iranian gardens, dwellings and even provinces. The gardens consisted of irrigation canals as well. The canals were constructed and positioned on a straight axis so that water was provided to the plants that were planted along the canals. With the spread of Islam and the influence of the Romans, the Persian garden style spread in the eastern direction to India and in the western direction to Spain.

More than half of the area of Iran is desert and an ancient tradition of building gardens aims to provide relief from extreme climatic conditions during summer and winter seasons. Persian gardens are seen as the practical and clear solution. Persian gardens tell a story about the voyage of water and the emergence of life after a struggle with the arid land and harsh climate. Water is the fundamental component and a primary attribute of Persian gardens, revealed in a very sophisticated and artistic way. Water is used for irrigating plants and at the same time its poetic and artistic statement decorates gardens and generates joy, bliss, vitality, movement and beauty. The water is distributed in a garden according to the archetypal cross-plan dividing the garden into four portions. This plan is called “Chahar Bagh” and emerged first in 550 BC in Pasargadae, which is the Royal Garden of Cyrus the Great, the king of the Achaemenian dynasty. This type of garden was the most remarkable innovation of that period and was regenerated during the following periods. In the eleventh century, a complex relationship developed between Persian gardens and the city and as a result, they became public sites (Fadaie and Mofidi, 2014).

Elements of Persian Gardens

Iranian gardens consist of four vital elements namely soil, water, plants and space. In harmony with each other, these elements make up the mental framework of Iranian gardens. However, other elements can be involved in creating gardens despite the fact that they are considered as auxiliary elements or minor components and manifestations of a garden’s principal components.

Soil; land is one of the major elements of a garden, and other factors including soil type, slope and level differences, irrigation feasibility and fertility are also significant in addition to the general shape and position. For example, due to the natural flux of water through the gardens, they are

constructed on steep land. Iranian gardens are constructed on land either with a low slope or a steep slope. In the case of a garden being constructed on a steep slope, this affects the garden type and they are constructed at various levels hence it is possible to create waterfalls (Shahidi, 2010).

Water; Flowing water is the most important element for raising interest and is sustained in Iranian gardens. Duct water flows in channels and streams and passes through the main stream and runs through lateral channels. Water is extant in at least three forms, namely, conceptual, functional and aesthetic. These forms can easily be discussed for instance, how water exists in the garden and how it runs and also in terms of water supplies and garden irrigation. Generally, ducts and springs are the main supply sources in many gardens, and the amount of water and its management and distribution determine the garden's area if done accurately and carefully. Garden irrigation is directly related with the land type and is important in Iranian gardens. Considering the lack of water in most regions of Iran and the respect and sainthood attached to water in Iran as well as the Iranian interest in applying water in gardens, Iranians used water in various ways in gardens and contributed to water's charm and grace.

Plants; plants are important because of their location, cultivation plan, elegance and usefulness in addition to their species and type. Plants play a role to protect gardens against devastating natural events. In Iranian gardens plants are used for numerous purposes including shade, yields, decoration and such. Usefulness is a very important aspect in Iranian garden construction and therefore fruit trees are planted extensively, shady trees are planted less frequently and ornamental trees are planted rarely. Generally trees are planted in gardens due to the hot and arid climate of Iran. Flowers and shrubs provide colour and scent.

Space; The last component of Iranian gardens is space or architectural space. Based on the definition of garden, the space or architectural space organizes the garden with an extensive discipline and creates areas and sections inside and outside the garden. In this context, structures, landscapes, interiors, ornamental elements and the relationship between water, plants and land are scrutinized. In Iranian gardens, closed spaces are integrated with open spaces and are not isolated from one another. We even see that water runs through these areas. Iranian gardens are surrounded by long uninterrupted walls built of adobe and not containing any ornaments (excluding the garden fences of ancient governors and local wealthy people). Thus, Iranian gardens serve as both a place for resting and safety. In order to take advantage of water, levels were selected and the water's path was graded, the sound of water gushing or trickling was

made more audible and the water running speed was controlled. Generally symmetrical water pools are built along the length of buildings in a visible section in front of the gardens or they are sometimes constructed as a basin inside ancient garden structures.

Geometry; This is the main concept of Iranian garden construction. It is very important that geometrical shapes are considered; square shapes are created for simplifying the sight of garden components and tree planting sites are designated accurately for the trees to be seen at any angle. The main axis is the focus in Iranian gardens which are surrounded by pathways generally and the main pathways divide the gardens into parterres which consist of plots.

The pools in ancient gardens are generally deep and contain several fountains. An example is the pool in Hezar Jaribe No Garden, Isfahan (Safavian Era) which consists of five hundred fountains. Round pools were predominant before and at the beginning of the Islamic period, however square or rectangular pools were built later on. Garden castles were erected in various locations in the garden. Castles were built in the middle of the gardens so that the main view was created along the garden's linear axis with a one-third ratio and there were points along the linear axis where the castle was constructed. The garden's lateral components were generally the manifestations of the garden's main elements and there were these manifestations and lateral elements in any of the main components (Ansari, 2011).

Bagh-e Fin (Fin Garden) in Kashan City

Bagh-e Fin was designed based on the principles of Persian Gardens and according to the dominating climate. This order is situated in various levels of the garden. Bagh-e Fin was configured to attain the maximum usage of plants considering the hot and dry regional climate. In other words, the garden design was made up of a plant system accompanied by the body system. The remains of the Fin museum-garden complex today in addition to the descriptions of its past illustrate that its garden mainly preserved its integrity and authenticity without major modifications (UNESCO, 2011).

Fin garden (Bagh-e Fin) in Kashan City was included in the World Heritage List of UNESCO in 2007 and has survived until the present as a unique example of Persian Islamic garden art. Bagh-e Fin is located in Kashan City of Iran. Bagh-e Fin covers an area of nearly 23000 m^2 and was built by Shah Abbas I in 1571 during the period of the Fin Safavid Empire (1531-1736). Bagh-e Fin was registered with the file number 238

in 1935 by the Ministry of Cultural Heritage. Bagh-e Fin is surrounded by tall walls and has four parts in its design (Chahar Bag). There is a mansion called Shotor Galauye Abbasi built by Shah Abbas in the middle of the garden. There are two historical Fin Bathhouses in the eastern section of the land. The small bathhouse was built during the Safavid Period and the large Fin bathhouse was constructed during the Qajar Dynasty period. There are water features in Bagh-e Fin designed as pools in the shape of conduits. The stagnant water in the conduits that are located in front of the structure is supplied by the square pool in Sefa-i Pool. Water was given movement with the use of water conduits and small sprinklers in the western direction. The water in the conduits in this portion is transferred to channels that are designed as steps from the large, square pool positioned in front of the building's western façade. The water used in this garden is received from the Selimiye fountain. Bagh-e Fin consists of 579 *Cupresuss sempervirens* and 111 *Platanus orantalis* trees. These trees are 100 to 470 years old (Moradi, 2014).

Fig. 2: Fin Garden

Bagh-e Dolatabad (Dolatabad Garden) in Yazd City

Yazd City is positioned 1215 m above sea level, surrounded by deserts and sandy fields. Shir-kooh with a height of 4075 m is the highest peak of the country. The Bagh-e Dolatabad monument survives from the Zands dynasty with an area of around 40,000 square metres and is considered as one of the most famous gardens of Yazd. Its main entrance is situated at its western side facing Dolat Abad Boulevard. However, the present public gate is situated on its southern side opposite the floodway (UNESCO, 2011).

The Dolatabad Garden's design is a special and exclusive official

Iranian garden. Its area is 6.7 hectares and it has a plan divided into two rectangular sections of 116,274 metres and 104,278 metres situated perpendicular to each other. The larger rectangle's symmetrical axis, now called Dolatabad Garden, forms the andaruni or interior garden that functioned as the private garden and housing of the governor and his family. The smaller rectangle on the northern side of the andaruni shows the exterior garden or biruni's outer border.

Fig. 3: Dolatabad Garden

Bagh-e Dolatabad consists of many trees, mostly pines, cedars and fruit trees. Among the fructiferous trees, there are grapevines and pomegranates planted inside *Karts*. There are pine trees situated in two rows along the garden's main axis and between the winter and summer mansions. These trees have been replaced over time and people always attempted to replace decayed old trees with young ones. An ancient mulberry tree is the oldest tree in the garden situated on the main entrance path.

Water runs prominently in Dolatabad. The main route of the Dolatabad Qanat was on its south eastern side behind the summer mansion and divided into two branches at the back of the building after it was linked to a small basin. One branch ran towards the cook house on the eastern side and the other branch was connected to the basin under the wind-catching structure and then entered the four basins inside the structure which were at a lower elevation in comparison to the first basin. Water entered the three basins outside the building here and subsequently ran into brooks at either side of the middle Kart and reached the frontispiece of the house. Subsequently, water entered a pleasant, now completely ruined water wheel (Abgardan). Afterwards, water emerged from under the frontispiece of the winter mansion, poured into a twelve-sided large pool, filled the three pools situated beside the first one and then reached village pathways

and agricultural lands.

Another conspicuous characteristic of Bagh-e Dolatabad is its historical Qanat dating back more than two hundred years. This Qanat consists of a series of five smaller ones stemming from the Mehriz highlands. After irrigating a portion of Mehriz fields and turning several water mills, the Qanat water joined the water of neighbouring villages including Abshahi, Khorramshah and Dolatabad and reached Yazd situated more than fifty kilometres away. The Qanat was closed at its origin at a later time unfortunately and in this way there was no water entering the city directly. Hence, Gavro, a traditional method, was used to provide the water necessary for the garden, where water was received from wells, and its basins were filled. However, the garden was not able to regain its former elegance and vitality. Today, a shallow well irrigates the garden situated opposite.

Conclusion

Islamic gardens were formed by the cultures and customs of various societies starting from the 7th century and emerged as a unique garden art depending on the effects of religion, climate and geography. Local and regional natural conditions including soil structure, climate, flora and ecology in different countries influenced garden development during garden art history. Islamic gardens were formed in regions with a hot, arid and slightly rainy nature considering the geographical locations where the Islam religion spread generally. Islamic gardens have always been regarded as the symbol of heaven and they were designed as daily living locations by imagining the eternal living desire there. Water and plants make up the most significant two components of the heavenly location in Islam religion. On the other hand, it is possible to see religious beliefs in plant material use. For instance, cypress, which is regarded as causing the soul to rise to the heavens especially in cemeteries, flowery almond expressing life and hope, and cherries are trees that are used as an expression of religious philosophy in Islamic gardens. For example, sycamores, defined as the life tree that is thought to express living strength, were used frequently in places where religious worship was practised, such as mosque backyards.

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CHAPTER 2

GREEN INFRASTRUCTURE SYSTEMS AND PRACTICES

SIBEL SARIÇAM AND BARIŞ KARA

Introduction

The social problems experienced in urban areas have come to the forefront especially with the ecological and social dimensions that exist. In spite of these problems, cities are still attractive living spaces for many people. According to studies conducted by the United Nations, more than 7 billion of the world's population live in cities. It is stated that 70 per cent of the world's population will live in cities by 2050. On the other side, cities are not prepared for the effects of climate change which is a global problem. Precautions devoted to climate change have been taken in developed countries and they are trying to find an effective solution to this indispensable change. One of these precautions is creating "green infrastructure" systems.

Climate Change and Its Effects on the Urban Ecosystem

Along with the fact that climate change and its effects have been revealed scientifically, it has been stated that this change will continue to increase in the following years (URL 1; 2).

It has been remarked that climate change will be felt the most in urban areas (Staden, 2014; The World Bank, 2011) and there is a bidirectional relationship between cities and climate change (Demirbas and Ozdemir, 2014). In other words, cities are the leader in damaging the environment by using up 78% of the world's energy consumption and creating more than 60% of the carbon dioxide and other greenhouse gases, although cities are only about 20% of the world's surface and are also the most affected by these changes (URL 3). What are the current and possible effects of climate change on the urban ecosystem? The direct effects of

climate change on settlements are hot or cold waves, extreme weather conditions (floods, aridness, etc.) and elevation in sea level. On the other side, its indirect effects include increases in cooling and heating expenses due to weather fluctuations, reconstruction costs as part of disasters such as floods, storms, etc., immigration to regions where there is low risk of disaster and increases in deaths and diseases (Demirbas and Ozdemir, 2014; The World Bank, 2011).

Therefore, it should be emphasized that climate change is not only an environmental problem but also a social and economic problem (URL 2). Unfortunately, climate change has still not been given enough respect in the management policies of many cities in spite of all the warnings which are being made currently (URL 3). Cities should adopt practices devoted to adaptation rather than waiting without taking any action against the effects of climate change or guarding against it (The World Bank, 2011). The "green infrastructure systems" are one of the most hope-inspiring practices among the strategies and actions being developed concerning adaptation to climate change (Gill et al., 2007; Jones and Somper, 2014; Foster et al., 201; Derkzen et al., 2017).

Green Infrastructure Systems

The scope of urban landscaping has switched to sustainable design principles from conventional planning and engineering principles of the 20th century and the green infrastructure system is one of those sustainable design approaches (Chini et al., 2017). In the 2020 Strategy of the European Union, an emphasis has been put on the green infrastructure system being more sustainable (European Union, 2013).

In general, this new strategy named green infrastructure aims to manage the flow of stormwater, decrease urban heat island effects, improve the air quality and support economic development and other sustainability targets (URL 4).

Benedict and McMahon (2002) define the green infrastructure as interconnected natural systems that include forests, woodlands, wetlands, parks, rivers, agricultural areas, etc., which help to protect public health and improve quality of life. The green infrastructure idea has a more comprehensive meaning when compared to the concept of "open area". Green infrastructure may be thought of as the sum of all natural sources (Firehock, 2013). It covers undeveloped areas as well as developed ones. In other words, it may have different forms, dimensions and usages and it may be public, semi-public or private. But its focus is the benefits that it provides to society (City of Unley, 2015).

Benefits of Green Infrastructure Systems

Beyond the adaptation to and fight against climate change, the green infrastructure offers a range of ecosystem services (Derkzen et al., 2017). Ecosystem services are the positive benefits that nature provides. These benefits include fresh air and water, recreational opportunities necessary for relaxation and to refresh our spirit, a nice landscape, natural heritage areas, rainwater remediation and healthy foods (Firehock, 2013). In this regard, "multifunctionality" is essential in the green infrastructures (Semiz, 2016; European Union, 2013; United States Environmental Protection Agency, 2016; Kramer, 2014, Natural England, 2011).

Green infrastructure benefits can follow under these three fundamental titles;

Environmental benefits: The green infrastructure systems play a significant role in terms of helping the people that live in the urban settlements to adapt to climate change (Forest Research, 2010). For example, conventional infrastructure systems direct the rainwater to water sources quickly and in turn damage the water quality by carrying all contaminants along with it and increase the flood risk. On the other side, the green infrastructure slows down the flow of rainwater, provides a place for the leakage effect to take place, decreases the flood risk, feeds the underground water and helps to protect the water quality while decreasing the urban heat island effect through evaporation (URL 5, Centre for Energy and Environmental Policy, 2012; Derkzen et al., 2017). Plants and soil are part of the green infrastructure system and undertake a significant role in the fight against climate change thanks to its functions as a carbon storage tool (National Conservation Foundation—Envirothon, 2012; Centre for Energy and Environmental Policy, 2012; Derkzen et al., 2017). The urban vegetation contributes by improving the air quality of the city via the trapping of some contaminants as they try to leave or absorbing them (National Conservation Foundation—Envirothon, 2012).

In green infrastructure studies, habitats are created for flora and fauna by protecting and using the natural vegetation areas that already exist (Forest Research, 2010). It establishes a connection with the large-scale areas such as green ways, parks and urban forests and helps to connect the wild areas to each other by giving them roads to achieve this (URL 6).

Economic benefits: While the materials belonging to the old infrastructure systems wear down and require maintenance over time, the green infrastructure practices mature over time and its resistance to wear and the beneficial effects actually increase as it adapts itself (Department of Urban and Regional Planning, 2013; Lindholm, 2017). Therefore, the

natural system offers cheaper and more resistant solutions while the creation of a grey infrastructure system and its subsequent maintenance costs become more expensive (European Union, 2013). The green infrastructure system can control the heat changes in the buildings with its functions such as being able to cast a shadow, evaporation and wind shear, decrease water consumption and accordingly, lower the costs by decreasing energy usage (United States Environmental Protection Agency, 2014).

On the other side, it is known that the value of properties and lands around green areas usually increases (Forest Research, 2010).

Social Benefits: In recent years, the increasing interest in the concept of ecosystem services and the focus on the economic contributions of green areas have also led to the increased interest in the social benefits they may have (Brink et al., 2016).

It is a known fact that green areas help to reduce stress and mental fatigue, and along with that they add a nice aesthetic appearance to a city (Forest Research, 2010). At the same time, they offer various opportunities for physical exercise. Therefore, the green areas are a significant tool in helping to create healthy communities both physically and mentally. Moreover they contribute to socialization, decrease the crime rate and violence, ensure interaction between different groups and social solidarity and create job opportunities (Brink et al., 2016).

Urban Green Infrastructure Components

Green infrastructure systems can be created both in the public or private area, at different scales, in public or rural regions and in different forms. Along with that, it is not an accurate approach to consider every green area as a green infrastructure area. It should not only be "green areas" that should offer more than this. For example; if an urban park filters the excessive water flow and provides a cold air corridor as well as being an attractive area for recreation and wildlife, it may be considered as an indispensable part of green infrastructure (European Union, 2013). Furthermore, its components shall be also interconnected in order that it may be accepted as a part of green infrastructure (Sanesi et al., 2017). Under this title, there will be an emphasis on urban green infrastructure components such as green roofs, green walls, rain gardens, bioswales, permeable pavements, green roads and streets, urban agricultural areas, urban forests, rainwater retention systems, etc. (Fig. 1).

Fig 1. Urban green infrastructure components

Green roofs and walls: The concept of a "green roof" is explained in two connotations. In accordance with the first explanation, it is a green roof if it is a living space used by a human that has a special and thin layer of substrate and vegetation. In accordance with the second explanation, a green roof contains vegetation and plants. Mostly, the aim of creating a green roof is to provide benefits to the environment by placing soil and vegetation on a roof that is coated with a waterproof membrane layer (Erkul and Sonmez, 2014). These systems may be defined as covering roofs in the city with living vegetation so as to change the structural system of a building slightly and without a need for irrigation or maintenance (Ekşi, 2016). Green walls consist of green facades which are created by covering them with specially designed supportive systems that allow for creeper-climbing plants (Green Roofs for Healthy Cities, 2008); in other words vertical gardens are defined as covering indoor or outdoor walls with rooted plants through a prefabricated modular panel or panel systems which are applied onsite (Ekren, 2017; Sclar, 2013).

Green roofs and facades have many benefits such as they decrease the urban heat island effect and noise, improve the air quality by filtering dust and smoke, support biodiversity, make a positive contribution to the urban