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A Comparative Study on Gardens of Isfahan and Shiraz From Sustainability View
(Case Studies: Gardens of Hashtbehesht and Jahannama)

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ABSTRACT: This paper will concentrate on the result of a research based on comparative study between two Persian gardens in different micro climates in arid regions. Sustainability could be observed in many aspects and elements of traditional Iranian architecture and landscape architecture, and this method of design has used to solve many problems for many centuries. Gardens of Iran have had special role to moderate hot and arid climate since many years ago and their design method is an appropriate strategy to create sustainable landscape in our today cities. In this research, the selected case studies are Hasht-Behesht garden in Isfahan, and Jahannama garden in Shiraz, located in two different areas in arid regions of central plateau of Iran. The research method adopted in this paper consists of descriptive-analytic and deductive analyses. By the analysis of sustainable and climatic features and characteristics of these cases, the main goal is to identify the parameters of creating green space for present and future sustainable landscaping with similar climates. Results confirm that the similarities and differences between these two gardens are because of the different microclimatic regions they are located in. At the conclusion part, the main characteristics of Persian gardens from sustainability view will be classified and recommendations for sustainable landscape design will be presented.

Keywords: *Sustainable landscape, Arid regions, Persian garden, Isfahan, Shiraz*

INTRODUCTION

The history of creation of Persian garden dates back to 6 (BC)[1] during the Acamenid era and the garden design in Iran had evolutionary process during the history till the 19th century. The studies show the first Persian garden was built in Passargad near the Shiraz by Cyrus the great in 6 (BC). This archetype of Persian garden is called Chahar Bagh, which means four gardens. The ancient royal gardens of Acanemid emperors with the palaces which were opened to the green spaces are called Pardice. “Pardice” means garden in Farsi and this word entered Semitic languages getting the form of, Hebrew Pardes, Arabic Ferdous and it is adopted in English as “Paradise”, expressing such gardens which have been closed with features based on climatic conditions and sustainable principles. The reminders of stone channels in Passargad were discovered by archeologist David Stronach during his excavation of that historical site and in his first depiction of Passargad (Fadaie &Mofidi, 2012); the rectangular Passargad garden has also pavilions and water channels (Fig.1). Until only a few years ago, there was a still prevalent opinion that the celebrated garden carpets of the sixteenth-century Safavid Iran provided the oldest extant evidence for the form of the early Persian garden. From the appearance of such carpets it was already clear that Safavid gardens included numerous water channels, multiple parterres, and a centrally placed garden pavilion which often stood within a rectangular pool on the long axis of the plan (Stronach, 1994, 3). The lack of green space in the vast arid regions in Iran is one of the main reasons to create many different gardens in the hot and arid regions. According to archeological findings described above, along with historical sources and also observations of current gardens of Iran, it can be concluded that the main design elements of Persian garden which are nearly the same in all of them are the grids of natural elements: water, vegetation and the built elements, pavilion which usually occupies minor axis and walls. Walls acted as borders between inside and outside. Other ancillary elements like service spaces (bath, stable) are also considered for arrangement of gardens. The compositions of natural and built elements in design are with

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respect to conceptual idea (axis), and the elements of garden are organized around it. Even though there are many similarities between Persian gardens of different arid regions, the reason could also be the similarities in tradition, but climatic condition is the main cause of differences between them. Since usually it is argued that landscape plans should be informed by species requirements, should show an understanding of supporting biological and physical processes, and should attempt to ensure process integrity (Boothby, 2013,281), so the main goal of this paper is first to investigate the similarities and differences between the microclimatic features of selected gardens as the case studies, and also to determine various sustainable design aspects of Persian gardens which can moderate the environmental condition.

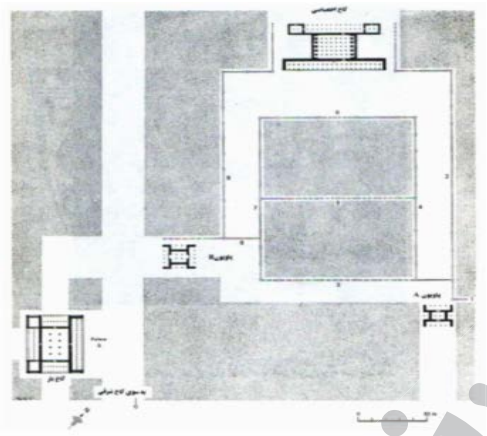


Fig.1: Passargad garden, Archetype of Persian Garden, Depicted by David Stronach
(Source: Khansari et al., 2004)

MATERIALS AND METHODS

The research methodology of this paper is descriptive-analytic, and deductive, based on historical and documented sources and field studies on physical aspects of selected gardens. Data collections of these selected gardens are conducted by use of studies and analysis of gardens' documents. Therefore, to collect the data, two methods have been used: library research and field study. The research framework of this paper includes these processes:

The recognition and descriptions of Hasht-Behesht and Jahannama gardens as selected case studies of this research.

The analysis of climatic conditions of locations of selected cases done by the Koppen's method with the use of data (temperature, amount of rainfall, humidity) of synoptic station statistics of Iran's weather website during ten years (1995-2005).

The analysis of Persian gardens' natural and built elements (water, vegetation and pavilion) and the role of sustainability to their creation.

A comparative study on selected gardens as case studies and their analysis from sustainability view. Through use of comparative method for analysis, the ability to distinguish the similarities and differences between selected gardens will be conceived.

Description of Case Studies

The selected case studies are two existing gardens in two different cities in arid regions of Iran. Selected gardens, previously used for royal ceremonies in Isfahan and Shiraz, are nowadays used as public gardens for leisure. Hasht-Behesht is the only surviving garden alongside the Chaharbagh Avenue (Hooshangi, 2000). This Avenue built in the Capital city of Isfahan in 17th century during Safavid era, was surrounded by extensive royal gardens and pavilions (Fig.2 and 3). Hasht-Behesht garden, also called Bolbol (nightingale) garden, was used for royal ceremony during hot summer days. During the history, many parts and elements of Hasht-Behesht garden and also the gardens, located around it, were demolished and nowadays, Hashtbehesht garden with its historical pavilion is the surviving part of the vast royal Safavid garden.

Fig.2: Hasht-Behesht garden and royal Chaharbagh Avenue during Safavid era Isfahan.
(Source: Iran Cultural Heritage Organization of Isfahan,2013)

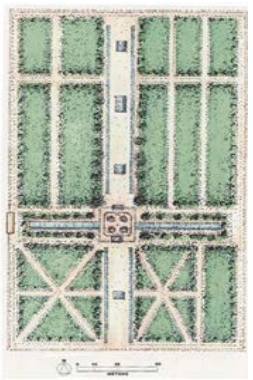


Fig.3: Plan of Hash-Behesht garden Isfahan.
(Source: Khansari, et al, 2004)

Jahannama garden is one the oldest surviving gardens of Shiraz. First, it was built in the 14th century but the garden was reconstructed and its main pavilion was created in 18th century during the Zandieh era, when Shiraz was the capital city of Iran. The garden was located outside the city, alongside the main road between Shiraz and Isfahan at that time, but gradually after the development of city, it has become an urban green space (Fig.4). Acccording to description of French traveler, Chardin (17th century), the road was the main Avenue of the city, which connected the Quran gate (main entrance gate of Shiraz) to Bazaar and the gardens placed opposite to each other alongside the road (Noroozborazjani, 2004).

Fig.4: The Location of Jahannama garden in Shiraz during Zandieh era (Source: Khansari et al., 2004)

Fig.5: Plan of Jahannama Garden in Shiraz (Source: Iran Cultural Heritage Organization of Fars, 2012)

Climatic Conditions of Isfahan and Shiraz

In Iran, there are many different geographical locations and climatic regions, each having special characteristics. As a result, Iran is like a little continent. Iranian scientists have worked on different climatic classification, and the most widespread method is by dividing climate of Iran based on Koppen's method, which has classified the world's climatic into five zones: Hot-Humid (A), Hot-Arid (B), Temperate (C), Cold (D) and Polar (E) climate. There are a few countries in the world, which contain the main four climatic zones (A, B, C and D); all of these climatic zones and their deviations can be found in Iran. The climate of central Iranian plateau is arid and semi-arid, and receives almost no rain for the six hottest months of the year. The main characteristics of this climate are also a very arid summer and cold winter. Furthermore, in this areas, most of the time, the sky is cloudless and the air does not have any humidity. Thus there are large differences between day and night temperatures. According to the Koppen's classification, the arid climate classification is based on: annual temperature, humidity and amount of rainfall, and is divided into four main microclimates: (BWhs) [2], (BWks) [3], (BShs) [4] and (BSks) [5] (Fadaie & Mofidi, 2012).

According to Koppen's classification (Table1) Isfahan is a deserted city (BW) and Shiraz is placed in stepped city (BS) of arid regions. The mean annual temperature of Isfahan is under18°C and of Shiraz is over18°C. Also, the amount of rainfall in both selected cities (Table1) reveals that, in the wettest month of winter, it is at least three times as high as that of the driest month of summer. Therefore, it could be concluded that Isfahan can be accordingly classified as BWks microclimates and Shiraz is located in BShs microclimatic area. Moreover, Shiraz is more humid than Isfahan. Also, in Isfahan the annual wind direction is often southwest and west while in n Shiraz it is northwest.

RESULTS AND DISCUSSION

Sustainable Features of Garden's Elements

Natural Elements: Water and Vegetation

Water and vegetation are natural elements of Persian gardens, which are acted as key ingredients in garden design. Since the gardens have been built in arid regions, water is used as an important design criterion to create a comfortable

Table1: Climatic Conditions of Isfahan and Shiraz[6]

City	Altitude	Annual Temperature	Temperature in Hottest Month	Annual Humidity	Annual Rainfall in Wettest Month of Winter	Annual Rainfall in Driest Month of Winter	Annual Rainfall in Wettest Month of Summer	Annual Rainfall in Driest Month of Summer	Conclusion
Isfahan	1550	16.6	29.2	35.5	46.3	4.4	1.5	0	BWks
Shiraz	1484	18.8	31.2	37.9	94.4	54	2	0	BShs

microclimate in Iranian gardens by channeling breeze over the existing water to reduce air temperature and increase humidity. Moreover, the extent of garden has followed the amount of it. Another important modifying element is vegetation, which has been utilized to guide and filter the breeze and to increase evaporative cooling by planting suitable vegetation, and also to provide shade and to absorb radiation by strategic location of them. Except for the central axis in Hasht-Behesht and Jahannama gardens, on which the pavilion is placed, the entire garden area is covered by vegetation. The vegetation in these gardens is used not only to increase the humidity, but also to create a comfortable environment by making shade and shadow. In both selected gardens, there are two items related to existence of water which have effective roles in creation of gardens as microclimates: the irrigation of garden and kind of water displays:

The Irrigation of Garden

Since both selected gardens are located in arid and semi-arid regions, the source of water and irrigation systems are two important factors to find water and prevent wasting it by evaporation. The source of water in Jahannama garden like many gardens of Shiraz was famous Qanat, Roknabad. Qanat is an indigenous method of irrigation, invented by ancient Iranians, carrying water from mountains bed through the interconnected wells, creating underground streams, and taking water to far-off places (Fig.6) and in Hasht-Behesht the garden was irrigated by streams flowing from the famous river of Isfahan; Zayanderood . Since in 17th century, during Safavid period, the agriculture of Isfahan city was intensified, there are ten streams, called Madi flowing from Zayanderood River to irrigate farms and royal gardens of Chaharbagh Avenue. The lack of sufficient water in such arid regions, led to create sustainable methods in irrigation system and water displays. The irrigation system influences the geometrical design of the garden, thereby preventing the waste of waste (Shahcheraghi, 2011).After the water irrigates the trees and other vegetation in each garden, and it flows outside the gardens to irrigate farms and other land.

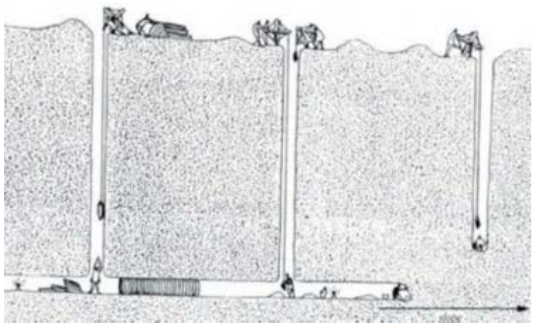


Fig.6: The Irrigation System by Qanat(Source: Khansari,et al.,2004)

Types of Water Display

There are different ways of designs by water, displayed in the both gardens. Large pool and pond to store water for drought seasons, canal and streams are employed to irrigate the plants. The settlement of four ponds around the main pavilion in both selected gardens is an important factor to increase weather humidity inside the building by channeling the breeze over the existing water. Also, the forms of cascades inside and outside the pavilions of Hash-Behesht and Jahannama could be observed respectively and many forms of fountains are demonstrated. The fountain and cascade are not just utilized for environmental beautification, but for increase of humidity during hot days.

Planting the Gardens

The historiacal documents show there were different kinds of vegetations in both selected gardens. Nowadays, only few flowers and trees have survived. Trees are used for three main reasons in Persian gardens; beautification, fruiting and shading. In Persian gardens the Evergreen trees were often placed in the main passageways to resist the storms and local dusty winds so as to be utilized as natural shading devices and fruit trees were planted between them. The adaptation of planting fruit trees to irrigation system, geometrical shape of garden and seasons, caused the gardens to always show sustainability and greenery (Fadaie & Mofidi, 2012). The existence of evergreen trees such as Cypress and Pine in the main passageway and fruit trees, like Sour orange and Pomegranate in Jahannama garden and also, Plane trees of Hasht-Behesht garden, reminds the planting order of Persian garden. Moreover, in Persian gardens, instead of lawn, spest is a kind of clover, used as pavement. Spest has different sustainable characteristics; that it absorbs nitrogen and transports it to the soil, repels insects, is easy to maintain, requires less water than grass, and can be used as cattle feed during cold seasons (Zamani et al., 2009, 36).

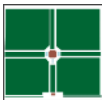
In spite of some similarities between the two gardens, there is a difference between the amounts of water in these gardens. As Table2 indicates, less amount of water is used in Jahannama garden, than Hasht-Behesht garden, because Shiraz is more humid than Isfahan during hot seasons. Since many parts of Hasht-Behesht garden have been destroyed during the history, it is too difficult to express the views about the difference between the amounts of vegetation of two selected gardens (Table2).

Furthermore, as the Table2 shows, the Jahannama garden is orientated according to Shiraz wind direction (Tables1and 2), but the orientation of Hasht-Behesht garden like other royal Safavid gardens of Isfahan is according to Stream (Madi) directions.

Built Elements: Pavilion

In spite of the most traditional urban buildings in the arid regions that are introverted, in the gardens like Hasht-Behesht and Jahannama, the built spaces like pavilions are extroverted. The reason could be the existence of massive texture of vegetation and water in the garden to create a desirable microclimate. The garden pavilions are analyzed from these points of views:

Table 2: Basic Data of Hasht-Behesht and Jahannama Gardens

City	Garden	Plan	Location	Orientation	Water			Plants			
					Source	Kinds of Water Displays	Pool Location	Area Percentage		Fruitful	Fruitless
Isfahan	Hasht-Behesht		In the Urban Fabric	E-W	Streams from River	Pool, Pond, Fountain& Streams	4Sides of Garden	1%	60%	-	Plane
Shiraz	Jahannama		In the Urban Fabric	NE-SW	Roknabad Qanat	Pool, Pond, Fountain& Streams	4Sides of Garden	0.3%	73.31%	Sour Orange Pomegranate	Pine& Cypress

Location and Orientation

The pavilions of Persian gardens are located on the main axis, from centre to the end of the garden. In Hasht-Behesht garden, the main pavilion, used as summery residence for royal family, was almost located in the centre and in Jahannama garden, the pavilion was placed in the centre of garden. In both gardens, the pavilions stood on the stone- faced platforms to prevent the entrance of dust in to the buildings. Both pavilions were opened in to four sides to utilize breezes from all direction, and also they were orientated to southwest, following the orientation of their gardens.

Passive Cooling Strategies of Pavilions

The most important strategies for passive cooling in building' s design in arid regions are: to provide shading and natural ventilation by wind and water. The mentioned strategies have been noticed for Persian pavilion design by creation of appropriate spaces and evaporative cooling elements for many centuries. Some of those strategies will be discussed below:

Iwan and Balcony

Iwan is a single vaulted hall which is opened into the outside and acts as a transition area, providing a link between inside the building and garden. It can be described as semi- closed space for passive cooling and also light adjustment and makes shade and shadow. The balcony is an isolated part of pavilion. The balconies are usually placed where they could have a panoramic view while remaining invisible to the eyes of strangers in the garden (Gharipour, 2009, 137-142). Also, Iwan and balcony act as semi- closed spaces to
use breeze. Each selected pavilion of this paper has four Iwans. In spite of similarities between selected pavilions, there are differences between the number and extent of balconies and openings. Although the area percentage of Iwan in the pavilion of Jahannama garden is more than that of Hasht-Behesht pavilion, the numbers of its openings is less than that of Hasht-Behesht pavilion (Table3).

Water Pond and Streams

In both selected gardens, there are central ponds inside pavilions for evaporative cooling in spaces. Although the physical effect of evaporation is essential, the psychological effect of water is even greater. The sound of water inside the building is known to bring relief. Furthermore, in both selected cases, the existence of ponds and water canals around the pavilions can modify airflow (Fig.8 and 9). Hot air can be cooled if passed over the water. The pond with its fountain in the northern Iwan of Hasht-Behesht pavilion makes the weather cooler and more humid during the hot summer days and in the southern Iwan, the flowing water from the pond in upper level, poured on the wall and then flowed into the pond of central space of ground floor (Tafazzol& Bahramian, 2013). In Jahannama pavilion, because of the location of building on 120cm platforms, the water from inside pond flowed in to the outsides ponds via four cascades (Fig.9). The placement of water ponds inside and around the both selected pavilions made the weather more pleasant for their residents.

Shading Devices

Use of shading devices is an important strategy in sustainable design. They should be designed to reduce direct solar radiation and prevent reflection onto any part of the building or opening (Fadaie &Mofidi, 2011). Both selected pavilions are protected from the intensity of sun by arcades and porches as shading devices. Moreover, in the pavilions placed in such hot and arid climates, the porch provides link from the building to the outside, keeping the sun off those under its roof and shading the structure it adjoins (Hooshangi, 2000). Another shading device in Persian Garden is wall, which acts as a shading device by creating shadow and also has other climatic functions such as protecting the garden against hot dusty winds while preserving humidity inside the garden (Shahcheraghi, 2010).

Building Materials

The main material used in selected pavilions is brick. Choosing brick has several factors to be considered: it has high thermal

Table 3: Characteristics of Hasht-Behesht and Jahannama Pavilions

City	Garden	Pavilion	Location	Orientation	Roof Design	Shading Device	Area Percentage%			Openings		Materials
							Closed Space	Semi-Closed Space	Water	Direction	NO	
Isfahan	Hasht-Behesht		Nearly in the centre	E-W	Dome	Arcade & Canopy	76.92	21.08	2	N S E W	16 22 21 16	Brick-Tile& Wood
Shiraz	Jahannama		Centre	NE-SW	Dome	Arcade	69.9	26	3.91	N,S E,W SE,SW NW,NE	1 1 2 2	Brick-Stone& Wood

Semi-Closed spaces Closed spaces Water Vegetation Built El

resistance, high thermal capacity and sun absorption. It doesn't require much energy to produce and also has the potential for reuse if the building is demolished. Furthermore, another vernacular material such as tile was utilized in some parts of Hasht-Behesht pavilion. These vernacular materials can be found resourcefully in arid regions (Table3).

Fig.7: Hasht-Behesht Pavilion in Isfahan

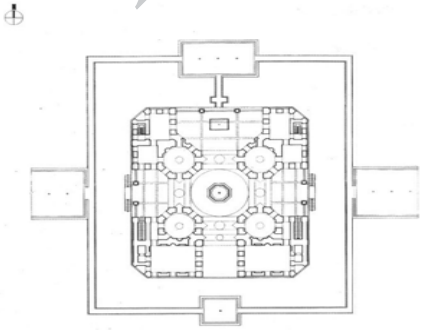


Fig. 8: Plan of Hasht-Behesht Pavilion
(Source: Iran Cultural Heritage Organization of Isfahan, 2013)

Fig.9: Jahannama Pavilion with its Outside Pond and Cascade.

Comparison of Architectural Features in Hasht-Behesht and Jahannama Gardens

From the above discussion and table indications, this information is obtained:

Both selected gardens are orientated according to wind directions;

The placement of pools all around the pavilions in both selected cases is the strategy for evaporative cooling in Persian gardens as sustainable green spaces in arid regions;

In both selected gardens, the pavilions are orientated according

to garden orientation;
As tables1and 3 indicate, in the hotter city, Shiraz, the amount of water in pavilion is more than that in Hasht-Behesht pavilion in Isfahan;
Since the intensity of solar radiation in Shiraz is more than Isfahan, the area percentage of semi-closed spaces in Jahannama pavilion is more than that of Hasht-Behesht pavilion.

CONCLUSION

This research shows that the objective of Persian garden design as traditional landscape architecture in arid regions has been to moderate local climatic components. Due to climatic factors, both selected gardens of this paper utilize natural soft and hard landscaping. Such landscaping helps to increase the passive cooling which contributes to Persian garden sustainability and ultimately by the analysis and a comparative method on the study of Hasht-Behesht and Jahannama gardens, the following conclusions can be obtained:
The characteristics of Hasht-Behesht and Jahannama gardens reveal that, in spite of many similarities in design and elements, there is little dissimilarity between them because of some differential climatic conditions. Climate even in a very close classification can be the main design determinant in the Persian gardens.
Persian gardens in arid regions by utilizing natural soft and hard landscaping can be considered sustainable method, which are not only influenced by climatic factors, but also have effective role to increase much needed passive cooling.
The irrigation systems of garden with the use of minimum amount of water in Persian gardens reveal the importance of sustainability in all social, economic and environmental aspects in traditional Iranian landscaping.

The orientation and layout of Hasht-Behesht and Jahannama Gardens are greatly determined by natural elements, such as sun, wind, and water, which are essential to Persian garden construction and sustainability.
The use of vernacular and sustainable materials (i.e. brick) with high thermal capacity and resistance in the built spaces of gardens in arid regions reveals the importance of using the sustainable materials in gardens of Iran.
In sustainable development model, considering social, economic and environmental developments is suggested. Since society includes a group of people and environment includes natural and built environments,, in Persian garden pavilion the relationship between human, built environment and nature is based on model of sustainable development (Fadaie&Mofidi, 2012).
The sustainable strategies in Persian garden design, mentioned in this paper, could be a contribution to the future of the profession of landscape architects and an appropriate solution for environmental problems of current cities.

AKNOWLEDGMENT

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ENDNOTES

1.BC abbreviation of Christian's era and stands for: before Christians.
2.BWhs: Desert climate with the average annual temperature over18°C.
3.BWks: Desert climate with the average annual temperature below 18°C.
4.BShs: Steppe climate with the average annual temperature over18°C.
5.BSks: Steppe climate with the average annual temperature below18°C.
6.Weather statistics used in this paper are retrieved from synoptic station statistics of Iran's weather website during ten years (1995-2005): http:// irimo.ir/statistics/synopH/index1.htm.

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