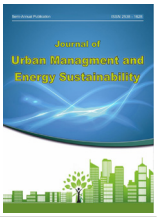
Int. J. Urban Manage Energy Sustainability, 3(3): 39-56, 2022

Journal of Urban Management and Energy Sustainability (JUMES)

Homepage: http://www.ijumes.com



ORIGINAL RESEARCH PAPER

Recognition of a Desert Garden through the Lens of Landscape Sustainability Case Study: Shazdeh Garden in Mahan, Iran

Honey Fadaie

Department of Architecture, Roudehen Branch, Islamic Azad University, Roudehen, Iran

ARTICLE INFO

Article History:
Received 2022-06-23
Revised 2022-09-14
Accepted 2022-12-17

Keywords:
Persian garden
Arid climate
Environmental sustainability
Sustainable landscape
Shazdeh garden

ABSTRACT

The Persian Garden as a symbol of a traditional Iranian landscape has a millennia-long history. A variety of factors contributes to create the historical phenomenon of which environmental sustainability is the important one. Although the Persian gardens have been investigated from different perspectives, knowledge about the sustainable perspective of these gardens is limited. Despite the importance of sustainability in traditional Iranian landscape, available studies have not examined the Persian gardens through the lens of sustainability. This paper scrutinizes the parameters of environmental sustainability in the historical garden of Shazdeh in the arid city of Mahan as a selected case study. The main aim of this study is analyzing the elements and design principles of Shazdeh garden in order to identify the features of sustainable landscape architecture. To this purpose, the selected research method in this paper is descriptive-analytical, which according to the type of research, study and data collection are the combination of these two qualitative and quantitative methods. In this regard, first, the qualitative method is used to examine the parameters of sustainable landscape in the hot and arid climate. Then, both qualitative and quantitative methods are employed to investigate and evaluate the effects of sustainability factors on the main elements of Shazdeh Garden which include natural elements (water, vegetation), and built elements (pavilion). The results show that understanding the characteristics of sustainable landscaping in arid regions play a key role in creating the physical models, spatial organization and composition of elements of Shazdeh Garden.

DOI: 10.22034/jumes.2022.1983338.1107

Running Title: Landscape Sustainability in Desert Garden

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
53	09	05

*Corresponding Author:

Email: *honeyfadaie@yahoo.com*
dr.fadaie@iau.ac.ir

1. Introduction

The lack of green spaces in big cities has become a great environmental crisis in these regions, so that, the coexistence with nature is the main concern of urban designers and landscape architects. Today, the construction of green space in accordance with climatic conditions and sustainable parameters is an important strategy to create a pleasant environment. Sustainable landscape is commonly a landscape that support environmental quality and conservation of natural resources (Roudie & Streich, 2009). A sustainable landscape is more than the conscious arrangement of outdoor space for human enjoyment and satisfaction. A landscape uses minimal water, fertilizers, pesticides, labor and building materials. Creating a sustainable landscape means working toward thoughtful balance between resources used–both in construction and in maintenance–and results gained. Sustainable landscapes require as much, if not more, planning as traditional landscapes. However, many traditional landscapes already contain some components of sustainability (Van Der Zanden & McNeilan, 2002). The historical gardens are part of traditional landscape. As historical gardens, such as Persian gardens contribute to passive cooling in hot and arid environments, understanding their characteristics can be the first step to design sustainable landscapes. The physical construction of the Persian gardens consists of three systems namely irrigation, planting, and construction (Shahcheraghi, 2010), and all these systems have a specific geometry. In other words, the main feature that distinguishes the Persian gardens from other gardens in the world is their geometrical structures (Mostafazadeh, 2008, 3) (Figure1). Each element and constituent systems of the Persian gardens

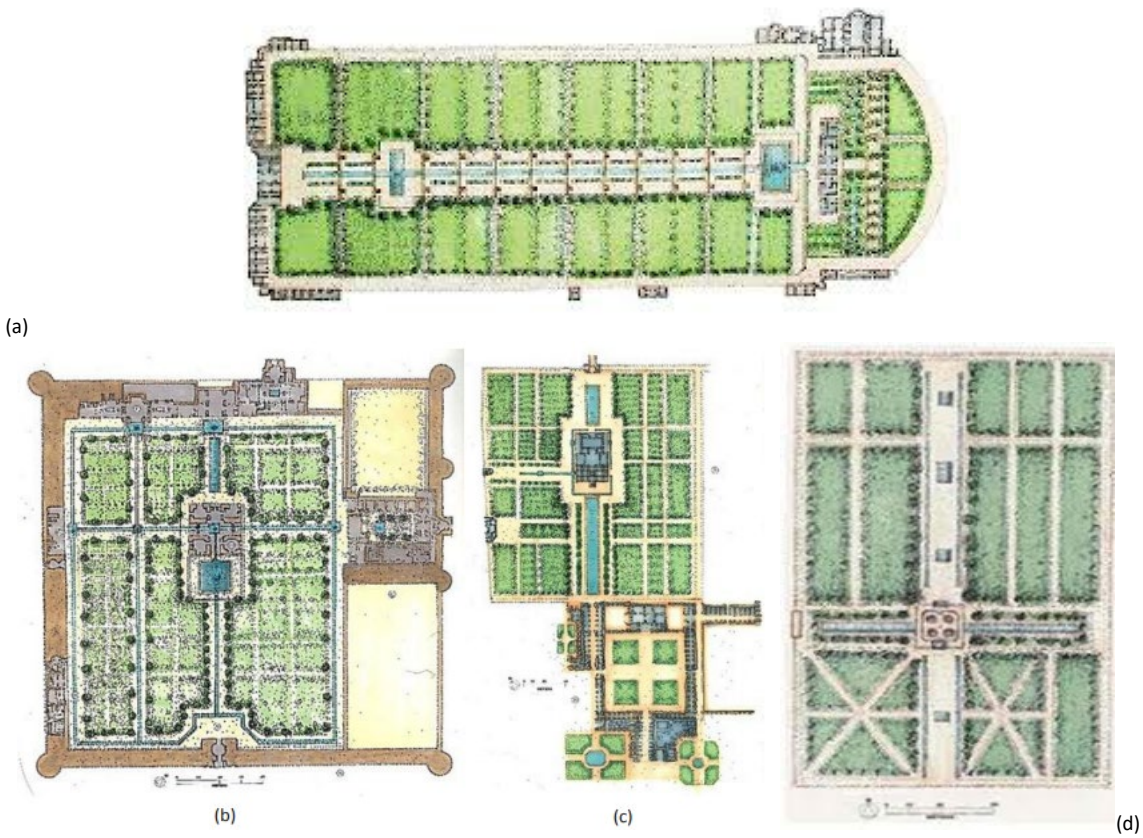


Fig. 1: Geometrical structure of different types of the Persian gardens in arid regions:(a) Shazdeh Garden, Mahan;(b) Fin Garden, Kashan; (c) Chehelsotoun Garden, Isfahan;(d) Hasht-Behesht Garden, Isfahan (Khansari, et al.,2003).

are based on sustainable design principles such as optimal irrigation, shading, and fruitful planting, optimum building orientation, high thermal capacity materials and closed walls.

This research focuses on parameters of environmental sustainability in the design of the Persian gardens as an appropriate strategy to develop sustainable guidelines for contemporary landscape designs. The main goal of this research is to investigate the characteristics of sustainable landscape design to define the criteria and patterns of sustainable landscaping, especially in arid regions. For this purpose, Shazdeh Garden was selected as the case study. This garden is located in the suburb of Mahan in the southeast of Iran. This historical garden, which has maintained its vegetation and architectural structure, has been registered by the Iranian cultural heritage organization, and it is a unique example of gardening in the desert (Figure 4).

It is hoped that selecting Shazdeh Garden as a valuable sample of the Persian gardens help to gain better knowledge about the sustainable features of these gardens and manage the landscapes sustainably to provide a comfortable for human beings.

The city of Mahan is located in 30,4N latitude, has hot days, especially during summer days. According to the classification system proposed by Köppen, Mahan is in a hot and arid desert climate (BW). Mahan has hot summers, relatively cold winters, and temperatures between days and nights are different. In this climate, the evaporation is always more than precipitation. Thus, the amount of rainfall is less in summer than in winter. In addition, high temperatures and low humidity are the most essential characteristics in the hot and arid climate (Pidwirny, 2012).

Furthermore, in Mahan, the winds usually blow from the northwest, and their speed maximizes during spring (Yamani et al., 2001, 20).

By the analysis of the sustainable feature of Shazdeh Garden, the main goal is to define the principles and parameters of sustainable the Persian gardens for contemporary landscaping.

The main purpose of this paper is to identify sustainable landscape criteria in the physical aspects and elements of historical Shazdeh Garden by answering the following questions:

"How do the environmental sustainability factors affect the designing process of Shazdeh Garden in arid regions"?

"Which characteristics of Shazdeh Garden can result in human comfort"?

1.2. Literature Review

Many contemporary scholars have explored the Persian gardens using a variety of approaches over the last fifty years. The studies conducted on the Persian gardens fall into two main groups: recognition and analysis of the features of the gardens. Among the studies, Prinia and Dneshdoost have explained the Persian gardens' geometry and their constituent elements (Pirnia, 1994; Daneshdoost, 1973). Norouzborazjani and her colleagues have described the features of different historical gardens, including Shazdeh Garden (Norouzborazjani et al., 2004). Shahcheraghi has explained the re-creation of the Persian garden designs in traditional and modern arts and presented the practical and physical parameters of the Persian gardens (Shahcheraghi, 2010). Some researchers have studied the constituent elements of the Persian gardens (water, plants, and pavilion) (Zamani et al., 2011), and others have specifically analyzed the built elements (pavilion) (Alemi, 2002; Gharipour, 2009). In the study on physical aspects of gardens, Katouzian has analyzed the relationship between the gardens and their sites (Katouzian, 1986). Alemi and Heydarnattaj scrutinized the original type of the Persian gardens (Alemi, 1986; Heydarnattaj, 2009). In recognizing the species of the Persian gardens, only Massoudi has elaborated Shazdeh Garden's elements and its systems of planting and irrigation (Massoudi, 2009). Some have explained historical gardens of the cities such as; Isfahan and Shiraz (Stronach, 1978; Arianpour, 1986.; Alemi, 1997; and Hooshangy, 2000). Among the scholars, Porter and Hobhouse investigated the Persian gardens from a religious and ritual point of view (Porter, 2003; Hobhouse, 2004). Mansouri has defined the aesthetic parameters of the Persian gardens through the lens of the ritual attitude (Mansouri, 2005). In analyzing the Persian gardens, a group of researchers has examined them from cultural and social perspectives (Stronach, 1990; Ansari,

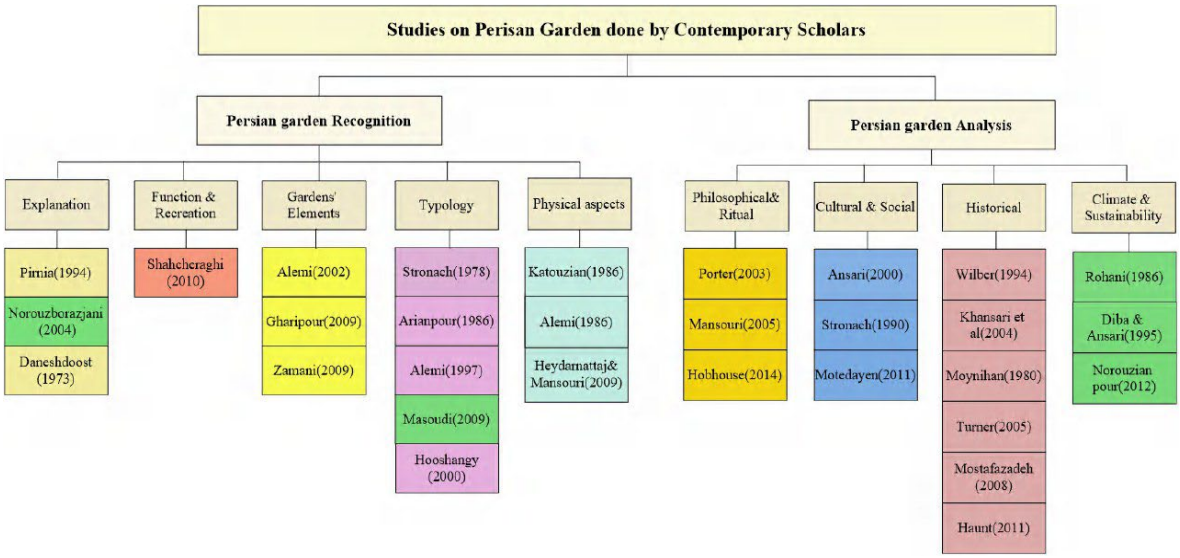


Fig. 2: Studies on Persian gardens carried out (Author, 2022)

2000; Motedayen, 2011). Many researchers have studied the Persian gardens using historical approaches. The garden historian, Tom Turner in his book "Garden History" has made a brief reference to garden design in Iran (Turner, 2005). Some researchers have described the Persian gardens in different cities from ancient times to the 19th century (Khansari et al., 2004; Wilber, 2005; Mostafazadeh, 2008, Hunt, 2011). Moynihan (1980) has explored the effect of the Persian garden design on later Islamic gardens. Some scholars have studied the sustainable and environmental parameters in the Persian gardens design without analyzing a specific case study. They have just mentioned the environmental characteristics such as garden orientation, planting, and shading methods in the Persian gardens' design (Rohani, 1986; Diba & Ansari, 1995; Norouzianpour et al., 2012).

Despite numerous studies on Persian gardens, only a few studies have examined the Persian garden designs from a sustainable perspective, and only two studies have been conducted on Shazdeh Garden (Figure2). Most studies have tended to describe the Persian gardens in relation to their historical background than the environmental aspects. Knowledge about this aspect regarding Shazdeh Garden is limited. This research scrutinizes the sustainable characteristics of Shazdeh Garden as a typical Persian garden to propose an appropriate design model for sustainable landscaping in arid climates.

2. Materials and Methods

The research method of this study is descriptive-analytical, and the data were collected from the relevant documents and field. A careful perusal of the documents was carried out on passive cooling design strategies in hot and arid zones, sustainable strategies in the main elements of landscape architectures, and climatic features of built spaces in arid regions, and the elements and design parameters of Shazdeh Garden.

A field survey was conducted on Shazdeh Garden to identify the parameters of sustainability in each element of the garden (natural and built elements) according to sustainable landscape and climatic principles in hot-arid climates.

In this study, the selected research method is analytical-descriptive, which according to the type of research both qualitative and quantitative methods were used to investigate the issue. The characteristics and sustainable features of Shazdeh Garden were first analyzed based on the qualitative method, and then the parameters of

sustainability in Shazdeh Garden were evaluated using the quantitative method. In other word in this paper, after describing the parameters of sustainable landscape and their comparative analysis with the design principles of Shazdeh Garden, their compliance percentage is assessed and identified quantitatively. Generally, the research procedure was as follows:

a- The parameters of environmental sustainability in landscape design in arid regions were described.
b- Sustainable strategies in Shazdeh Garden were investigated.
c- The environmental sustainability of Shazdeh Garden was assessed.

Finally, the data obtained from the present study were used to identify the Shazdeh Garden's aspects as an oasis in an arid region.

3. Results and Discussion

3.1. The Principles and Parameters of Sustainable Landscape in Arid Regions

A sustainable landscape as a part of the concept of sustainable development pays close attention to natural resources. Sustainable landscaping creates a balance with the local climate and environment. The main factors of the sustainable landscape are appropriate function, cost efficiency, visually pleasant scenes, friendly environment and maintenance. Moreover, it reduces the pollution of air, water, and soil by minimizing the use of pesticides and chemical fertilizers (Klette & Cummins, 2014). The proper vegetation and the optimal irrigation methods are the other main factors contributing to sustainable landscape design (ibid). According to the "American Society of Landscape Architects "(ASLA) description," sustainable landscapes are responsive to the environment, re-generative, and can actively contribute to the development of healthy communities. Sustainable landscapes sequester carbon, clean the air and water, increase energy efficiency, restore habitats, and create value through significant economic, social and environmental benefits" (asla.org, 2019).

The "US Green Building Council Leadership" developed "Sustainable sites" (landscape) as one of the six categories of the "LEED" certificate in 1998. LEED certification is awarded on a point system and addresses categories such as water efficiency, sustainable sites. "Landscapes are addressed primarily under the "water efficiency" category with rating points allowed for reducing water used by 20 to 50 percent, using no potable water (or no water at all), and innovative wastewater management technology" (Cook & Vanderzanden, 2010, 10). Another term for sustainable landscape is" The Sustainable Sites Initiative" (SSI). It has the intention to produce guidelines that enable built landscapes to support ecologic functions by protecting the existing ecosystem and regenerating ecological capacity where it has been lost (ibid, 12).

As stated in the above descriptions, the main instructions of sustainable landscape consist of avoiding water waste, which is harmful to the environment, planting useful vegetation, using renewable materials, and finally considering local climatic conditions. Since the main elements of the landscape are divided into soft elements (i.e., water, vegetation) and hard elements (built materials) (Pineo & Braton, 2009), we decided to analyze the parameters of sustainability based on three landscape elements. According to the environmental conditions of hot-arid climates, the main climatic purposes in architecture and landscape design in that area include solar preservation, natural ventilation, and resistance against the prevailing dusty winds. Thus, the main criteria in the sustainable landscape are as follows:

3.2. Water Elements and Irrigation Systems

Studies show in many cities, 40-60 percent of water is used in sites (Mc Krenney & Terry, 1995, 327). For that reason, in a landscape design, the applicable solutions to reduce water evaporation and prevent water waste are using optimal irrigation and drainage methods (Klette & Cummins, 2014). In hot and arid regions, air movement from outside, during the midday hours can increase discomfort, as the air is very hot. Under these conditions, it is necessary to reduce ventilation and exclude external air movement unless the incoming air is cooled before entering" (Nielson, 2002, 122). Air movement by passing over the water elements (pool, pond, and canal) can decrease weather temperature and obtain humidity from water.

3.3. Vegetation and Planting Systems

Residents of hot areas use outdoor spaces during the day only when they are shaded. The enclosure walls provide shade inside the Persian garden, especially during summer days. Moreover, installing verandas, porticos and covered walkways by trees can be effective methods to reduce glare and create shaded spaces (Rohani, 1986, 95). One of the most important factors in sustainable landscaping is choosing the vegetation and planting system. These should be restricted to the species, which can survive with very little water (ibid, 62). Planting native plants can maintain the ecosystem, and reduce energy consumption. Native plants need less preservation compared to non-native plants (Benson & Roe, 2007, 190). Planting fruitful trees by the native plants in urban texture create a landscape consistent with the parameters of sustainability (Sheibani & Chamanara, 2012, 19-21). Furthermore, the plants can create a sustainable landscape and modify the climate in the following ways:

3.4. Modification of Sunlight

The plants absorb the heat, provide shade and create insulation. They decrease the daytime temperature by absorbing the heat of the sun during the day and releasing it at night. Furthermore, each plant has its own texture, which determines the density of its shadow (Lesczynski, 1997, 100). The type of vegetation and planting method adjust the solar radiation. Trees, shrubs, groundcover such as lawn and clove are major factors against the heat of the sun. Evergreen and deciduous trees have their own characteristics to moderate climate (ibid).

3.5. Change in Moisture

Plants play an important role in controlling moisture, especially in hot and arid regions. Plants can increase water particles in the air through evaporation and transpiration, and consequently, increase weather humidity (Rohani, 1986). Studies show that "moisture reaching the air that is intercepted by plants is absorbed better than moisture falling on exposed soil; the plant slows down the rate at which water comes in to contact with the ground, as precipitation, decreasing surface runoff and soil erosion" (Lesczynski, 1997).

3.6. Wind Control

Plants, especially trees adjust the speed and direction of winds by obstruction, guidance, filtration, and deflection (ibid, 100). One of the essential ways to adjust the wind speed and direction is planting according to the shape, texture, height, and location of plants. For example, evergreen trees, such as cypress, play an important role in controlling dusty winds in arid zones throughout the year (Rohani, 1986).

3.7. Water Preservation and Soil Protection

Some special techniques can preserve the water. The "Green Industries of Colorado" coined the term "Xeriscaping" for the first time to eliminate supplement water for irrigation. Optimizing the use of water through special plants is the main purpose of xeriscaping (Sarami, 2012). Xeriscaping is a strategy in landscaping to preserve water resources (ibid). There are different methods for xeriscaping for instance planting limited lawn or grouping the plants with the same watering requirements together (Mc Krenney & Terry, 1995). Moreover, groundcover plants protect the topsoil from erosion and drought (ibid).

3.8. Built Elements and Materials: Passive Cooling Strategies

Another important factor in sustainable landscaping is using local, renewable and low energy materials. The use of low energy materials prevents the release of toxins into the air (Pineo & Braton, 2009).

As it was mentioned, the main climatic purposes in architecture in hot and arid climate include solar preservation, natural ventilation and resistance against the prevailing dusty winds. Table1 shows the main design strategies to achieve human comfort according to climatic objectives in hot and arid region. It also indicates these climatic strategies in various parameters of built environment, such as building's form and orientation, elements (entry, floor, etc.) and color and materials (Table1). These are the most important strategies that scholars pointed out.

3.9. Case study: Description of Shazdeh Garden and its Sustainable Characteristics

Shazdeh Garden is an oasis in the desert, located on the slope of a mountain in southeast of Iran, in Kerman province, 6 kilometers away from Mahan. The main axis of the garden is north-south (Fadaie & Mofidi, 200,750). The enclosed walls around the garden preserve it from the intensity of solar radiation and dusty winds, which blow from the west and northwest

Table 1: Climatic Design Strategies in Arid Regions According to Scholars' View

Design Parameters		Climatic Objectives		
		Solar and Heat Preservation	Natural ventilation and Increasing Humidity	Dusty Winds Control
Form & Orientation		Using -rectangular shape, orientated to the E-W axis to gain less solar radiation (Watson and Labs, 1997). -Orientating the Pavilion to the southeast to obtain less heat (Fadaie, 2016).	Building's orientation should be according to the wind directions (Watson and Labs, 1997, 130).	-
Elements of Buildings	Entry	Setting a foyer between the main entrance and building to act as a filter keeping the heat out of the building (Watson and Labs, 1997, 214).	Setting a foyer between the main entrance and building to let air get into the building (Watson and Labs, 1997, 214).	Setting a foyer between the main entrance and building to act as a filter for the hot and dusty winds not to find a way to the building (Watson and labs, 1997, 214).
	Floor	Designing the basement to control the fluctuation between day and night temperatures with the high thermal capacity of the earth (Fadaie, 2016).	Designing the water elements (e.g., pond) to provide evaporative cooling inside the building.	-
	Wall	Minimizing the walls in the east and west sides to reduce heat gain during the day (Watson and Labs, 1997, 214). Using the horizontal and vertical shading devices according to walls' orientation (Nielson, 2002, 78).	-	-
	Opening	Designing the openings for several purposes (e.g., day lighting, natural ventilation) (Nielson, 2002, 82-84).	Openings with different sizes in different height of walls and roof to ventilate the weather by stack effect.	-
	Roof	Designing the domed roofs to protect the building from solar radiation exposure and reduce the heat (Nielson, 2022, 72).	Designing the vertical elements for natural ventilation such as wind catchers, solar chimneys on top of the buildings.	-
Color & Materials		-Using the materials with high thermal resistance and capacity to receive heat and cool off the climate inside (Soflaee, 2003,146) -Using Light color reflect the heat	-	-

by providing shade. The walls also protect the humidity inside the garden, thus the garden acts as a closed ecosystem (Figure 4). Except for the central axis of the garden, on which the pavilion and cascades are placed, the entire garden's area is covered by vegetation (ibid, 754). Moreover, the parameters of sustainable landscape in Shazdeh Garden in three systems of irrigation, planting, and architecture are explained in relation to the main elements of the garden (water, plant, and pavilion) as follow:

3.10. Water and Irrigation System

The source of water supply, Irrigation method, and type of water displays, are three important factors in the irrigation systems of the Persian gardens. Like other Persian gardens, in Shazdeh Garden, the system of water irrigation is in accordance with the geometric form of the garden, this compatibility cut down water consumption through the garden. One of the most interesting mechanisms related to Shazdeh Garden is the assessment of the garden area. A century ago, based on the assumed amount of water for garden irrigation, the garden designers determined the size of the garden and its tree types. (Massoudi, 2009).

3.11. Water Sources and Irrigation Techniques

The source of water in Shazdeh Garden is "qanat" which is located in the nearest mountain called "Tigaran". Qanat is a vernacular method of irrigation, which was invented by ancient Iranians. This underground system carries water from the mountain beds to far-off places through the interconnected wells (Figure 5). In Shazdeh Garden, except for the main axis and the two adjacent streams where the water is constantly flowing, in other streams, water only flows when the garden is irrigated (ibid, 199). After irrigating the trees, the running water is directed toward outside the garden to irrigate other fields and gardens. This method can decrease water evaporation and prevent water waste.

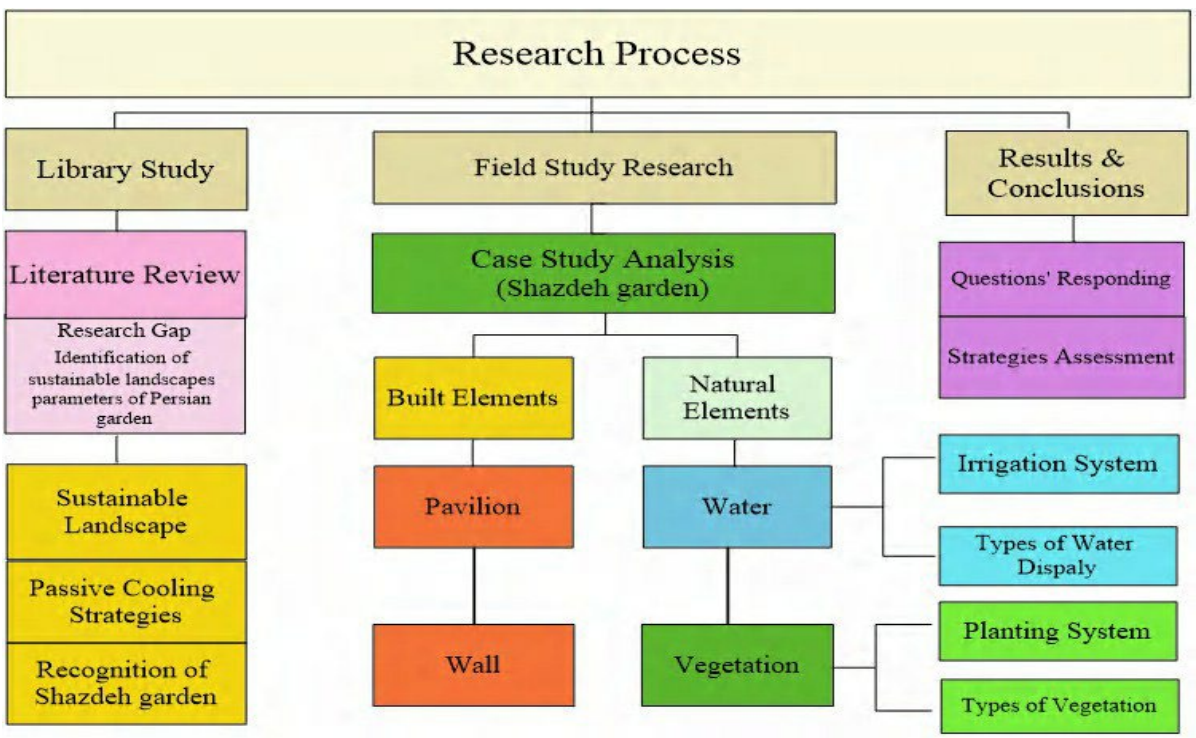


Fig. 3: Research Process (Author 2022)

3.12. Types of Water Display

In Shazdeh Garden, there are different water displays such as pools, streams, ponds, and cascades (Figure 6). In fact, a stream on the main axis of Shazdeh Garden is an intelligent and unique combination of nine water ponds with the same number of cascades (ibid, 196). Placing various water elements throughout the garden can increase the evaporative cooling by blowing wind on the surface of the water (Fadaie, 2016).

Fig. 4: Shazdeh Garden, Mahan (Norouzborazjani, 2004)

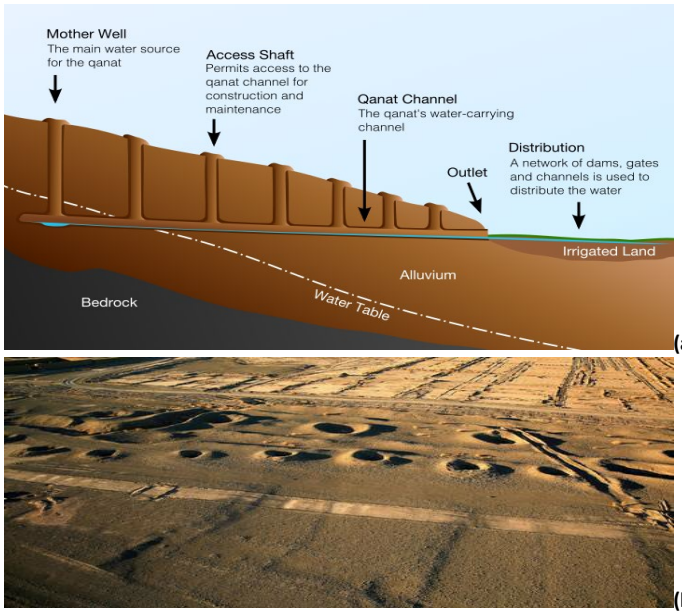


Fig. 5: (a) A cross section of a Qanat (Wikipedia.org); (b) An aerial Photo of a Qanat (whc.unesco.org)

3.13. Vegetation and Planting System

Plants in Shazdeh Garden are evergreen trees (e.g., Cypress, Pine, Plane, and Poplar) and inside the orchards, fruit trees have been planted symmetrically in line with the main axis (Heidari & Behbahani, 2009). Inside the garden, shaded trees are organized along the irrigation networks. In other words, planting and irrigation networks are based exactly on the geometrical structure of the garden. Shaded trees have been planted along the walls and on the main passageways (Figure 7). In this garden, Plane trees are planted at the beginning and end of each sub-axis and Cedar trees are placed in the distance between

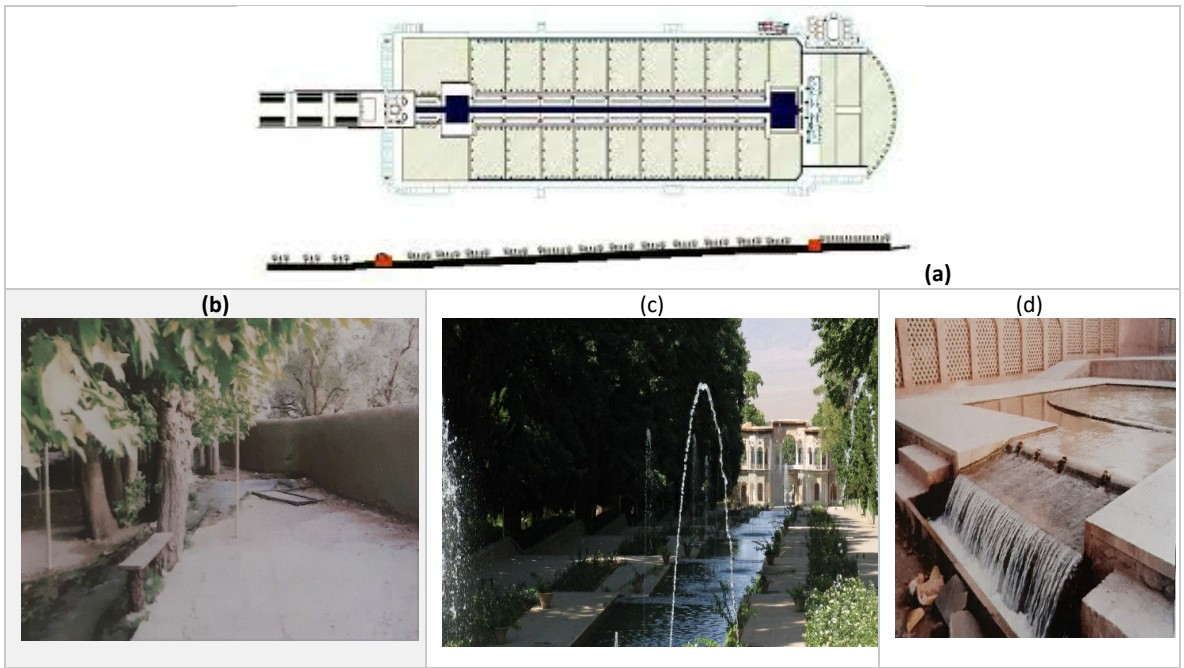


Fig. 6: Different water displays in Shazdeh Garden: (a) pools and canals (Persiangarden.ir, 2008); (b) water enters the garden and water streams run beside the trees; (c) water cascades and fountains; (d) display water outflows into the garden (Massoudi, 2009)

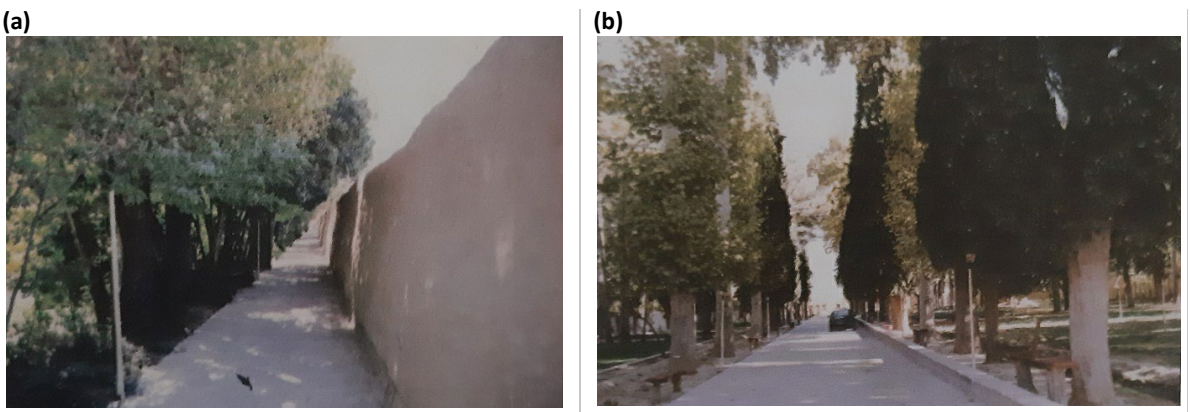


Fig. 7: (a) Planting shaded trees near the wall ;(b) planting evergreen trees on the pathways (Massoudi, 2009).

the axes. They create shadows for the pathways of the sub-axes as well. The shaded trees have been planted only on the pathways and the borders between the two orchards. Central and adjacent passageways create shade, and fruit trees inside the orchards are exposed to solar radiation needed (Norouzborazjani et al., 2004). Deep and extensive roots of the trees take water from the depths of the soil layers and protect them from erosion (Norouzian Pour et al., 2012).

A field study of Shazdeh Garden and its main three systems show that the vegetation covers 62% of this garden (Figure 8), especially planting the evergreen trees beside the passageways has a significant effect on absorbing and controlling intense sunlight and provide shade (Figure 7). As the garden geometrical structure is in accordance with planting and irrigation systems, water supply canals in the garden can optimize water consumption. The prevailing winds in Mahan

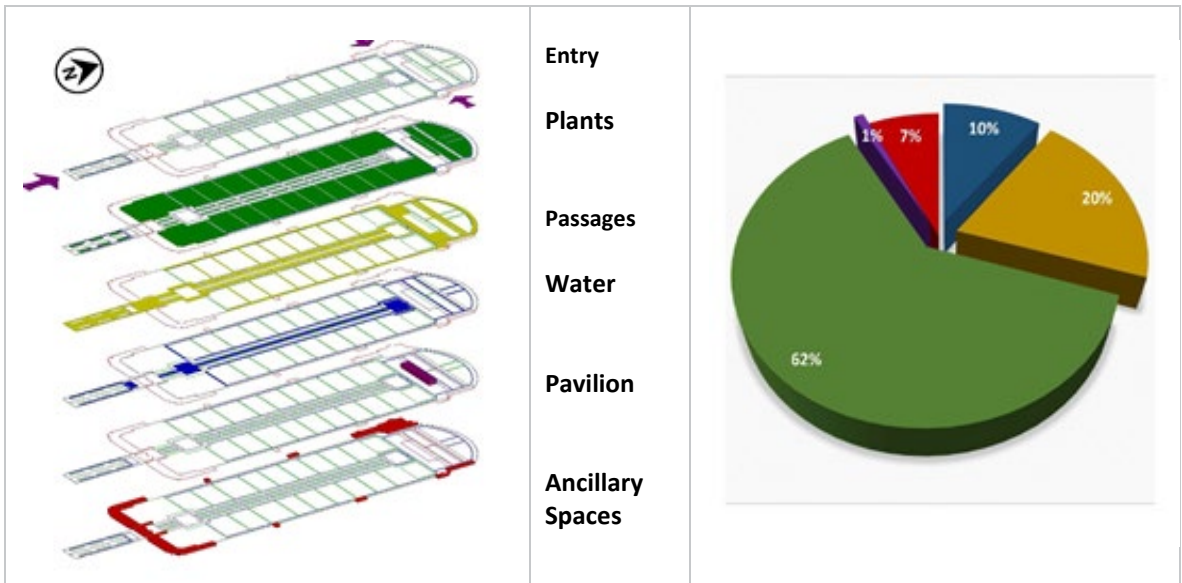


Fig. 8: Adaptation of irrigation and planting systems with the garden geometry and the percentage of area constituent elements of the garden (Fadaie, 2016)

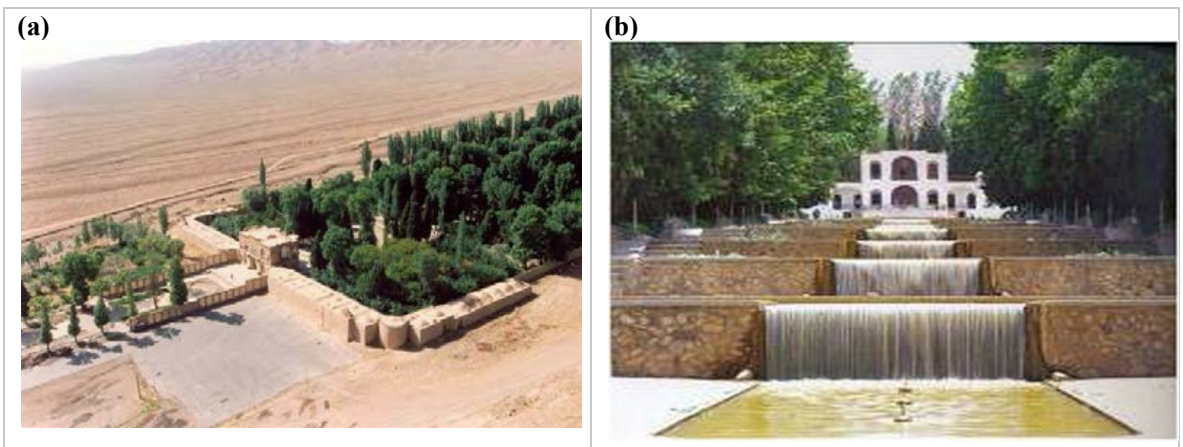


Fig. 9: (a) Wall acts as a border between garden & desert (Persiangarden.ir, 2008) ;(b) Shazdeh Garden pavilion (Norouzborazjani, 2004).

from the west and northwest directions carry sand with them. The rows of evergreen trees in the northern and southern axes of the garden block disturbing winds as well as intense solar radiation (Figure 8).

Planting kind of local shrub plant called "Espes" in Persian in the orchards is another sustainable strategy in Shazdeh Garden as well as other Persian gardens. "Espes" is a type of Alfalfa with various sustainable characteristics. For instance; low water consumption, sunlight absorption, and reduction of air temperature (Zamani et al., 2009).

3.14. Built Elements: Pavilion and Wall

The pavilion and the wall are the main built elements of the garden., Like other Persian gardens, Shazdeh Garden has spatial services such as bath, stables, etc. However, these spaces do not play a role in shaping the geometrical shape of the garden. Therefore, in this section, only pavilion and wall are discussed:

3.15. Pavilion

The pavilion of Shazdeh Garden and many other Persian gardens are extroverted though the most of urban buildings in arid regions are introverted. The climatic reason could be associated with the existence of massive textures of water and vegetation in the garden, which creates desirable microclimates. Furthermore, due to the existence of local dusty winds in Mahan, there is not any aperture on the east and west sides of the pavilion (Fadaie & Mofidi, 2009, 756).

Table 2: A Comparative Study on Design Strategies in Shazdeh Garden and Principles of Sustainable Landscaping

Parameters of Sustainable Landscape			Description
Irrigation	Reducing water evaporation	■	Using straight and perpendicular water canals, the of water streams under the trees' shades, somewhere under the ground can reduce water evaporation
	Optimizing the use of water and avoiding waste of water	■	Using straight and perpendicular water canals, irrigating the garden through Qantas, storing the water in elements such as ponds, pools
	Appropriate drainage and prevention of damage		There is no evidence
	Aligning the irrigation system with planting system	■	Figures 6 and 8
	Percentage of Compliance :75%		
Planting	Using native and deficit water plants	■	-
	Planting Fruitful trees	■	Planting fruit trees in orchards in different steps
	Not using pesticides &chemical fertilizers		-
	Planting evergreen and deciduous trees for their shade	■	The deciduous trees in the south side, around the pavilion, don't make shade
	Planting evergreen trees to protect the garden from storm and dusty winds	■	Planting evergreen trees in the main sides of the garden to protect it from the local dusty winds
	Planting the deficit water plants to control the flood		There is no need for controlling the flood since waterfalls are of small height
	Percentage of Compliance:66.6%		
Materials	Using local and renewable materials	■	Using adobe as the main materials in buildings
	Using durable materials with low energy consumption	■	-
	Using non-poisonous materials without poisoning	■	-
Percentage of Compliance: 100%			
Percentage of Compliance in Shazdeh Garden: 80.5%			
■ Compliance			Noncompliance

Table 3: The Compliance of Design Criteria of Natural Elements (water, vegetation) of Shazdeh Garden with Climatic Objectives in Arid Zones

Climate Objectives	Planting		Water & Irrigation	
	Criteria Assessment	Comments	Criteria Assessment	Comments
Solar Preservation & Decrease the Heat	Shading the walkways by evergreen trees	Planting evergreen trees (e.g., pine & cypress (on the main axes can modify sunlight and absorb the heat (Fig.7)	Cooling the garden through directing airflow over the different water resources	Cooling the garden through different water displays: pools, ponds, streams, cascades & fountains (Fig.6)
	Planting evergreen trees on the main axes to decrease the temperature and absorb solar radiation	Planting Pine & cypress trees can modify sunlight & absorb the heat (Fig.7)		The garden consists of 10% of water, with thermal resistance act as an insulator (Fig.8)
	Planting the shrubs to decrease the temperature and absorb solar radiation	Planting clover in the orchards can reflect solar radiation	Water running under or close to the trees can decrease the temperature	-
	Modifying the temperature absorbing solar radiation by increasing the vegetation coverage	Planting 62% of the garden's area (Fig.8)	High capacity of the sources of water prevents the absorbed heat to be transferred to the environment	The large pools and cascades with the fountains on the central axis of the garden decrease the temperature (Fig.6)
	Increasing humidity radiation by increasing the vegetation coverage		Increasing humidity by water running near the trees	There are water streams under the pine trees (Fig.6)
Natural Ventilation & Increase Humidity	Planting the shrubs to preserve humidity and avoid wasting water	Planting clover in the orchards to prevent wasting water	Using passive cooling techniques such as positioning pools, ponds, and streams in the direction of the pleasant wind	There are different water displays (e.g., pool, pond, fountain) to increase humidity (Fig.6)
	Planting deciduous trees windward to direct the breeze	Directing the wind inside the garden and into the pavilion by planting the rows of the trees (Fig.7)	Increasing humidity by making the pools, cascades , and streams in windward	-
Dusty winds Control	Planting evergreen trees to control dusty winds	Planting evergreen trees in the perpendicular axes of the garden to change the dusty wind direction from the east to west	Modifying dust by creating the water elements (e.g., pool, pond...)	Water elements are positioned throughout the garden

Despite the garden orientation (north-south), the pavilion is extended alongside the east-west axis because of climatic features in hot and arid zones (Table1). The form of roof, just like other buildings in arid climates is in a dome form. As mentioned in Table1, a domed roof will always have part of its surface in shade during the day. At night, a domed roof' s large surface area means a greater area from which a long-wave radiation heat loss can occur (Nielson, 2002, 72).

In addition, the pavilion is made of brick and has high thermal resistance and sun absorption. The bricks with white stucco plaster reflect the heat of the sun from the pavilion.

3.16. Wall

In Shazdeh Garden, the wall acts as the border between two different environments. Like many other Persian gardens in desert areas, in this garden, the wall provides the shade and preserves

Table 4: The Compliance of Design Criteria of Built Elements (Pavilion) in Shazdeh Garden with Climatic Objectives in Arid Zones

Climate Objectives	Built Environment (Pavilion)	
	Criteria Assessment	Comments
Solar Preservation & Decrease the Heat	Using walls to preserve heating by shading and enclosing the garden	Walls around the garden create an oasis in the arid climate
	Placing the main pavilion façade towards the garden	The pavilion is positioned on the1/6 end of the garden to employ pleasant weather of garden
	Positioning pavilion in northwest-southeast orientation	The pavilion is positioned in east-west direction
	Using few openings on the eastern and western sides of the pavilion	There are few openings on the east and west facades
	Using the thermal heating by having parts of the building underground	Using the basement floor and high thermal mass of the earth
	Controlling shading & sunlight through creating a porch, balcony	There is a large balcony in front of the main entrance
	Using a curved roof to modify heating absorption	-
	Using local renewable materials	Using brick (renewable& local materials) in the pavilion construction Covering the building by white stucco plaster
Natural Ventilation & Increase Humidity	Preserving the garden humidity by surrounding its walls	Surrounding garden by adobe walls
	Creating cross ventilation inside the pavilion by placing the openings on its opposite sides	The northern and southern openings are positioned opposite each other
	Placing the pavilion near water elements (i.e., pool, ponds, canals)	There is a water pool in front of the southern façade
	Creating a physical connection between the pavilion & water elements (ponds, canals)	-
	Using passive cooling strategies inside the pavilion	-
Dusty Winds Control	Decreasing or removing openings in to the dusty wind direction	Minimizing the eastern and western sides of the pavilion
	Using the foyer to prevent dusty winds from entering	-
	Placing water elements (pond, etc.) inside and around the pavilion	There is a water pool in front of the pavilion

Table 5: Assessment the Compliance of Natural & Built Elements in Shazdeh Garden with Climate Objectives

Climate Objectives	Criteria and Adaptability with Climate Objectives in Arid zones					
	Planting		Water and Irrigation		Built Element (Pavilion)	
Solar Preservation & Decrease the Heat	Shading the pathways by evergreen trees	■	Cooling inside the garden by airflow over the different water elements; pool, pond, canals, fountain	■	Walls preserve heating by shading and enclosing the garden	■
	Planting evergreen trees on the garden axes to absorb heat and decrease the temperature	■	Water sources; pools, etc resist against thermal heat	■	The settlement of the main pavilion façade in the garden	■
	Planting the shrubs in the orchards to absorb solar radiation	■	Creating evaporative cooling in the garden by having water streams near and under the trees	■	Positioning the pavilions in the northwest-southeast	■
	Modifying sunlight and decreasing heat by increasing the vegetation coverage over 50%				Creating few openings on the eastern & western sides of the pavilion	■
					Employing thermal heating by placing parts of the building underground	■
					Shading & radiation by creating a porch, balcony	■
					Using a curved roof to modify heating absorption	■
					Using local renewable materials	■
Natural Ventilation & Increase Humidity	Increasing humidity by increasing the vegetation coverage over 50%	■	Increasing humidity in the garden by water streams near and under the trees	■	Preserving humidity inside the garden by building the surrounding walls	■
	Planting the shrubs in the orchards to avoid wasting water and preserving humidity	■	Using passive cooling techniques such as positioning streams in the direction of the pleasant wind	■	Providing cross ventilation inside the pavilion by creating the openings of opposites sides	■
					Building the pavilion near water elements (e.g., pool, ponds, canals)	■
	Planting deciduous trees windward to direct the breeze	■	Using different water displays (e.g., pool, ponds) to increase humidity	■	Creating a physical connection between the pavilion & water elements (ponds, canals)	■
					Creating passive cooling inside the pavilion by designing spaces (e.g., porch) and placing elements (e.g., porch, wind catcher)	■
Dusty winds Control	Planting evergreen trees to control dusty winds	■	Modifying dusty winds by placing water elements (ponds, canals) in their directions	■	Decreasing or removing openings in to the dusty wind direction	■
					Placing the foyer between the entrance and main space to prevent dusty winds from entering the garden	■
					Placing water elements (pond, etc.) inside the pavilion	■
	Noncompliance			■	Compliance	

the humidity in the garden. The shape of the wall is in proportion to the geometrical pattern of the garden and its construction is completely in accordance with the slope of the land (4.5%). Planted trees inside the garden and adjacent to the wall act as additional elements separating the garden from the outside desert entirely. Additionally, the trees provide a more suitable environment for other plant species inside the gardens by providing shade. Furthermore, the garden wall with a row of adjacent trees protects the garden from sand and dusty winds (Massoudi, 1389, 188).

4. Assessment of Sustainable and Climatic Strategies in Shazdeh Garden

By analyzing sustainable landscaping features and design strategies in arid climates, and explaining the principles and elements of the design of Shazdeh Garden, the criteria based on environmental sustainability as the important parameters in landscape designing were investigated. Accordingly, Table 2 shows the sustainable characteristics of the elements of Shazdeh Garden, compares them with the principles and parameters of sustainable landscapes with natural systems (irrigation and planting), and built elements (pavilion). As climate plays a key role in the creation of natural and built elements of Shazdeh Garden, tables 3 and 4 show the compliance of natural and built systems of the garden with climatic objectives. Table 5 shows the extent to which natural and built systems in Shazdeh Garden comply with sustainable principles in arid zones. The compliance with the mentioned standards is shown using black and white squares. Compliance is indicated by white squares and non-compliance by black squares. In this regard, according to Tables 2 and 5, the ratio of black squares to all sustainability parameters and climatic objectives is determined as the percentage of compliance with the mentioned parameters and objectives. Finally, the average compliance percentage of each of these parameters and objectives is considered as the compliance percentage of the entire garden with the principles of environmental sustainability.

5. Conclusion

The environmental sustainability view is the main difference of this research from other studies on Persian gardens, thus this study attempted to develop sustainable criteria in Persian garden design, especially in arid areas. Among the few studies conducted on the role of sustainability in Persian garden design, this research has scrutinized the sustainable characteristics of Shazdeh Garden as a typical Persian garden to propose an appropriate design model for sustainable landscaping in arid climates. While the previous studies referred to the sustainable characteristics of Persian gardens in a descriptive method without any analysis, the present paper investigates the Shazdeh Garden as a case study and analyzes its elements from the perspective of sustainability. To this purpose, the climatic factors in natural and built elements of Shazdeh Garden as a sample of the Persian gardens in the hot and arid region of Mahan were analyzed and the principles and frameworks for sustainable landscape in arid regions were evaluated (Tables1-5). Analyzing data show that in Shazdeh Garden, the compliance percentage of the systems of irrigation, planting, building to sustainable parameters are 100%, 100%, and 81.2%, respectively, while this value for the garden design is 93.75%. Furthermore, as the tables (1-5) indicate, the climatic objectives as the most significant factors of environmental sustainability such as, solar preservation, decrease heat, natural ventilation, and increasing humidity and so on, are perfectly in the compliance with the garden's elements design. These findings respond to the first question "How do the environmental sustainability factors affect the designing process of Shazdeh Garden?"

The findings demonstrate that in Shazdeh Garden, there are reasonable parameters corresponding with the sustainable landscape design. In other words, the main achievement of this paper is identifying sustainable characteristics of Shazdeh Garden as a remarkable traditional Iranian landscape in arid climate. Results of this study show how the environmental sustainability factors have affected the designing process of Shazdeh Garden in arid regions. Analyzing the

data regarding the research questions shows that the natural and built elements of the garden are in line with the climatic objectives in the arid regions, for instance, solar preservation, natural ventilation and dusty winds control. Thus, the mentioned concept and features create a closed ecosystem in an arid zone with the other sustainable landscape characteristics like, using shaded and fruit full trees and optimizing use of water for irrigation and decoration of the garden, explain which characteristics of Shazdeh Garden can result in human comfort and respond the second question of present paper.

The evaluation and assessment of elements and characteristics of Shazdeh Garden represent a model of principles and parameters of sustainable design in the historical Iranian landscape. This model of landscaping is based on human comfort and design strategies that are compatible with the environment, according to the climatic conditions of the arid areas. Thus, this model can be generalized to hot and arid climatic areas by performing similar investigations.

References

Alemi, M. (1986) Chaharbagh, Environmental Design, Journal of Islamic Environmental Design Research Centre (1) 38-45.

Alemi,M.(2002). Persian Gardens and Courtyards: An Approach to the Design of Contemporary Architecture, in: Attilo Petroccioli and Khalil.K.Pirani, understanding Islamic Architecture. London, Routledge. P: 75-80.

Alemi, M. (1997). The Royal Gardens of Safavid Period: Types and Models. Gardens in the Time of Great Muslim Empires, Theory and Design, ed: Attilio Petroccioli. Brili. Leiden. Newyork. Koln. P: 72-96.

Ansari, M. (2000) Values of Persian Garden (Safavid Isfahan), unpublished Ph.D. Dissertation, Tehran University, Iran.

Aryanpour, A. (1986) Research of Recognition of Persian Garden and Historical Gardens of Shiraz Yasavoli, Tehran.

Benson, J., Roe, M. (2007), Landscape and Sustainability. Taylor & Francis, Uk.

Cook, T.W., Vanderzanden, A.M. (2010) Sustainable Landscape Management (Design, Construction and Maintenance), John Wiely, UK.

Daneshdoust, Y. (1973) Islamic Gardens in Iran, les jardins de I′islam, ICOMOS44-53.

Diba, D, Ansari, M. (1995). Persian Garden.In proceeding: 1th Congress of History of Architecture and Urbanism Tehran: Iranian National Heritage Organization: 25-42.

Fadaie, H. (2016) Iranian Gardens in Arid Regions from Sustainable View, unpublished Ph.D. Dissertation, Science & Research Branch, IAU, Tehran. Iran.

Fadaie, H.; Mofidi, S.M. (2009). A Comparative Study on Sustainable Landscape in Arid Regions (Case Studies: Mahan and Fin Gardens in Iran). In proceeding: 1th International Conference on Sustainable Architecture and Urban Development. Tripoli, Libya, pp. 749-759.

Gharipour, M. (2009) Pavilion Structure in Persianate Gardens Reflection in the Textual and Visual Media, Ph.D. Dissertation, Georgia Institute Technology, USA.

Heidari, F., Iranibehbahani, H. (2009) Persian Garden, Hamshahri: Tehran.

Heydarnattaj, V., Mansouri, S.A. (2009) A Critical Study on Chaharbagh Theory in Creation of the Persian Gardens, Bagh- E Nazar: The Scientific Journal in the Field of Theoretical Studies of Art and Architecture 6(12) 17-30.

Hobhouse, P. (2004) Gardens of Persia, Kales Press, San Francisco.

Hooshangy, F. (2000) Isfahan City of Paradise, A Study of Safavid Urban Pattern and Symbolic Interpretation of the Chaharbagh Gardens, unpublished Master′s thesis, Carleton University, Canada.

Hunt, Patrick. (2011). Persian Paradise Gardens: Eden and Beyond as Chaharbagh. Electrum Magazine, why the pastmatters.(http://www.electrummagazine.com/2011/07/paradise-gardens-0f-persia-eden-and-beyond-as-chaharbagh).

Katouzian, SH. (1986) The Sense of Place in the Persian Garden, Environmental Design, Journal of Islamic Environmental Design Research Centre (2)42 -47.

Khansari, M., Moghtader, M.R., Yavari, M. (2003). The Persian Garden: Echoes of Paradise, Mage Publishers,UK.

Klett,J.E.; Cummins, A. (2014).sustainable landscaping. In: Fact sheet.No.7.243, Colorado State University (http://www.ext.colostate.edu/pubs/garden/07243.htm).

Leszczynki, N.A. (1997). Planting the Landscape; A Professional Approach to Garden Design, John Wiley and Sons Inc Publishers, New York.

Massoudi, A. (2009). Acquaintance with Iranian Gardens; Baghe- E-Shazdeh, Faza Publication, Tehran.

Mansouri, S.A. (2005) An Introduction to the Aesthetics of Iranian Garden, Bagh- E Nazar: The Scientific Journal in the Field of Theorical Studies of Art and Architecture2 (3) 58-63.

Mckenney, C., Terry, R. (1995) The Effectiveness of Using Workshops to Change Audience Perception of and Attitudes about Xeriscaping, Hort Technology5 (4) 327-330. https://doi.org/10.21273/HORTTECH.5.4.327

Mostafazadeh,M. (2008) Design of Persian Garden Museum Based on Iranian Culture in Garden Making, Master′s thesis, TM, Tehran, Iran,(https://parseh.modares.ac.ir/thesis)

Motedayen, H. (2011) Causes of Appearance of Iran′s Historical Gardens, Bagh- E Nazar: The Scientific Journal in the Field of Theoretical Studies of Art and Architecture 7(15) 51-62.

Moynihan,E. (1980). Paradise as a Garden in Persia and Mughal India, George Braziller INC, New York.

Nielson, H.K. (2002). Stay Cool: a Design for the Built Environment in Hot Climates, James & James,UK.

Nourouzborazjanie, V. (2004). Persian garden: Ancient

Wisdom, New Landscape. Tehran contemporary Art Museum.
Norouzian Pour, H., Motahari, M.; Motaghi pishe, S. (2012). Persian Gardens are Sustainable Gardens: Scrutinize the Sustainability Features in Persian Gardens. In proceeding: 2th International Conference on Architectural Transition through the Silk Road. Nishinomiya, Japan, 280-285
Pieno, R., Barton, S. (2009) Sustainable Landscape Materials and Practices, Sustainable Landscape Series, University of Delaware. (Retrieved April 5, 2014 from http://extension.udel.edu/factsheet/sustainable-landscape-materials-and-practices).
Pirnia, M. (1994) Persian Garden, Iranian Journal of Abadi 4(15) 12-23.
Porter, Y. (2003). Palaces and Gardens of Persia. Translated to English by; David Radinowicz. Flammarion,Paris.
PIDWIRNY, M. (2006) Climate Classification and Climatic Regions of the World, Fundamentals of Physical Geography. (Retrieved from: http://www.physicalgeography.net/fundamentals/7v.html
Rohani, G. (1986). Garden Design and Green Space Construction, Farhang Jame, Tehran.
Roudi, S.; Streich, A.M. (2009). Landscape Sustainability. University of Nebraska, Institute of Agriculture and Natural Resources. (Retrieved Jan 2022 from: https://extensionpublications.unl.edu/assets/pdf/g1405.pdf
Sarami, J. (2012) Design the Environment and Landscape of Arid regions based on Xeriscaping and Localization Approach Based on Environmental and Cultural Conditions of Country Case Study: Central Campus pf Isfahan University, Master's thesis, Tehran University, Iran.
Shahcheraghi, A. (2010). Paradigm of Paradise (Recognition and Re-creation of Persian Garden), Jahad Daneshgahi, Tehran.
Sheibani, M., Chamanara, S. (2012) Productive Urban Network A Strategy for Achieving Sustainable Development, Manzr: Iranian Open Access Journal of Landscape4 (20) 18-23
Soflaee, F. (2004). Sustainability of Climatic- Sensitive Elements in the Iranian Traditional Architecture of Hot-arid Regions. In proceeding: 3th International Conference in Fuel Conservation in Building, Tehran, Iran.pp:133-155. https://en.civilica.com/l/3191/
Stronach, D. (1990) The Garden as a Political Statement, Some Case Studies from the Near East in the First Millennium B.C, Bulletin of the Asia Institute (14) 171-190.
Stronach, D. (1978). Pasargadae. A Report on the Excavations Conducted by British Institute of Persian Studies from 1961-1963, Clarendon Press, Oxford.
The Persian Qanat: Qanats of Bam. Retrieved from :(https://whc.unesco.org/en/documents/141555: May2020)
Turner, T. (2005). Garden History (Philosophy and Design, 2000B.C-2000A.D), Soon press London & New York. https://doi.org/10.4324/9780203589335
Van Der Zanden, A.M., Mc Neilan, J. (2002). Basic Design Concepts for Sustainable Landscapes. Oregon State University.
Watson, D.; Labs, K. (1983). Climatic Design (Effective Building Principles and Practices). Translated in Farsi: -Ghobadian, V. Feizmahdavi, M. (1997). Tehran University.
What are Sustainable Landscapes? Retrieved from: The American Society of Landscape Architects (ASLA) (http://www.asla.org/sustainablelandscapes/about.html:Oct2014)
Wilber, D.N. (1994). Persian Garden & Garden Pavilions, Tuttle Publishing,Tokyo.
Yamani, M., Zahabnazouri, S.; Goorabi, A. (2001) Assessment of Morphometry and Lodgment of Kerman Reg by Characteristics and Granolumetry of Sands, Journal of Arid Regions Geographic Studies 1(4) 17-33.
Zamani, E., Leylian, M.R., Amirkhani, A., Okhovat, H. (2009) Recognition and Analyzes of Persian Gardens' Elements with Respect to Ethical Principles, Bagh- E Nazar: The Scientific Journal in the Field of Theoretical Studies of Art and Architecture 6(11) 25-38.
https://en.wikipedia.org/wiki/Qanat: May2020
https://persiangarden.ir: Retrieved: Nov 2008

HOW TO CITE THIS ARTICLE

Fadaie, H., N. (2022). Recognition of a Desert Garden through the Lens of Landscape Sustainability Case Study: Shazdeh Garden in Mahan, Iran. J Urban Manage Energy Sustainability, 3(3): 39-56.

DOI: 10.22034/jumes.2022.1983338.1107