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Evaluating the Role of the Spatial Configuration of the Iranian Garden in Environmental Sustainability as a Development Framework (Case Study: Abbas Abad Garden, Behshahr)

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Abstract

The present study analyzes the physical system of Abbasabad Garden in Behshahr, as one of the most prominent examples of Iranian gardens, and examines its impact on environmental sustainability. By combining natural and artificial elements, this garden offers an outstanding model of sustainable interaction between architecture and nature. The focus of the present study is on three main components including water system, planting system, and building system, each of which plays a fundamental role in improving environmental quality. The research method was carried out with a mixed approach including field studies, statistical analyses, and structured questionnaires, and data were collected through direct observation, interviews with experts, professors, and surveys of tourists and analyzed with SPSS software. The findings show that the Abbasabad Garden water system has been able to manage water resources optimally by using reservoirs, canals, and engineered structures. The planting system, by utilizing native, drought-resistant vegetation, has reduced soil erosion and increased ecological sustainability. Also, the building system using local materials and compatible with the region's climate has improved energy efficiency and created greater adaptability to environmental conditions. The results of this research show that Abbasabad Garden is an inspiring example of sustainable design that can be used as a practical model in contemporary environmental and urban planning. This research emphasizes the need to restore and protect this valuable heritage in order to strengthen environmental sustainability and preserve cultural identity.

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Introduction

Despite the fact that environmental issues are a priority in planning today, we still witness the implementation of projects that are implemented without considering environmental impacts (Liu et al., 2022, 19; Gholamian Hosseinabadi et al., 2022, 92).

Historical gardens are a valuable part of human heritage that have environmental, economic, social and cultural benefits. The identity of historical gardens is formed based on natural elements such as plants and water. The ancient art of Iranian gardening since the Achaemenid period has been a manifestation of the integration of nature and architecture (Fadaie and Mofidi Shemirani ،2021 ،81) and It is also a symbol of Iranian architecture, which is the result of a flow-oriented approach to the environment - the product of a unique multi-layered network of living systems within a geographical area. The Iranian garden represents the alignment of the cultural and natural context and is a sign of the harmony and alignment of man and nature.

In addition to their beauty, these gardens play a role in the sustainability of the landscape and help regulate a rich ecosystem. From the archetype to the Islamic era campuses, the art of Iranian gardening has focused on storing and displaying water, creating a microclimate, and locating it correctly, using traditional water systems, using native plants, and designing architecture in harmony with nature. Because these approaches help optimize natural resources, reduce water consumption, and preserve ecosystem diversity. These views, which demonstrate the crystallization of environmental sustainability in the Iranian garden, have been widely endorsed by experts, archaeologists, architects, historians, and artists (Adapted from: Fadaei and Mofidi Shemirani, 2021, 40; Shahcheraghi, 2014; Mohammad Alinejad and Ghasemi-Nasab, 2016, 21; Ansari and Saleh, 2012, 83; Qaedamini Haruni et al., 2014, 238; Nobar and Rahimi, 2014). Given that the Iranian garden has a real identity and belongs to the Iranian society, in order to protect it, effective strategies must be implemented that specifically address its social, economic and environmental sustainability. This requires a transdisciplinary approach that brings together the knowledge of citizens and different communities, methods and scientific disciplines (Fouladi and Rahimi, 2024). Academic interest in the conservation of historic gardens began in the 1980s, when the Florence Charter formally recognized historic gardens as living monuments. The Florence Charter is a set of international policies for the conservation of natural heritage that have evolved since the 1960s and serve as guiding documents. For example, non-binding declarations issued by international bodies such as the United Nations, UNESCO, ICOMOS, and national institutions such as the United States National Park Service include international treaties and laws that often protect these gardens as a side effect while focusing on other issues, particularly environmental protection (Funsten et al, 2020, 31).

Environmental challenges such as water scarcity, soil erosion, deforestation, and pollution (air, water, and soil) have put human security and well-being at serious risk and have become a major global issue (Shams al-Dini et al., 2020, 89; Allahyari et al., 2022, 96). These challenges, which have affected some historical Iranian gardens today, have also manifested in Abbasabad Garden in Behshahr in the form of a decrease in the lake's water level, the destruction of part of the tree cover, encroachment on the natural forest's boundaries, and environmental pollution (Adapted from: Heydarnetaj, 30,2018; Heydarnetaj, 2023).

This indicates the lack of a proper relationship between urban development and environmental planning, which has created contradictions in maintaining the integrity of forest ecology. Researchers emphasize the use of environmental knowledge to create a sustainable structure to combine traditional and modern knowledge to provide a planning framework (Radaei et al., 2021, 10492). This systematic review of the literature on the management of the Abbas Abad Historical Garden in Behshahr focuses on the environmental aspect of sustainability. This study aims to address one of the dimensions of sustainability (environmental) in the physical system of the Iranian garden. This paper seeks to help solve the global environmental problem with a new and possibly more effective approach and perspective; Therefore, the main goal of this study is to express the effects of the physical system of the Iranian garden on environmental sustainability. Also, the main question of the present study is: Which

features of the physical system of the Iranian garden play a more effective role in strengthening and maintaining environmental sustainability?

Theoretical Framework

Persian Garden

Iranian gardens are divided into two categories in the Islamic encyclopedia: public and private, and consist of three main systems: functional system, semantic systems, and physical system, which is a combination of natural and artificial elements such as water, plants, and buildings. Also, landscape, shadow, and sound systems are the result of combining the components of the physical system (Shah Cheraghi, 2009, 81; Habibi Khozani and Akbari, 2021, 4). The physical system of the Iranian garden varies from region to region, depending on the climatic and cultural conditions of each region (Ariaei et al., 2018, 1296). Due to the multifunctional nature of historic gardens, they include agricultural, industrial, residential, nature conservation, and recreational zones (Funsten et al., 2020, 3). The architectural pattern of the Iranian garden is divided into two parts: extroverted and introverted. Extroverted gardens have features such as a four-garden design, a pool or pavilion at the intersection of axes, a connection between the inside and outside of the building through ponds and water features, planting trees in regular rows, creating bird nests and cages, tiled waterways, lattice walls, extensive lawns, high walls, and dense vegetation (Ansari and Saleh, 2012, 86; Goodarzi, 2017, 392). The introverted gardens are centered around a central courtyard, with surrounding buildings that are part of traditional Iranian architecture. The design contributes to environmental sustainability by emphasizing environmental conservation, reducing dependence on fossil fuels, natural cooling, reducing air dryness, and creating climate comfort (Mohammad alinezhad ،2020 ،19). In addition to their productive use, historic gardens provide a foundation for ecological considerations in urban gardening by preserving soil and crop health. These gardens emphasize the value of native plants, the conservation of local species, and traditional landscaping (Khalilnejad, 2021, 30). Plants control climate conditions by creating shade and transpiration and create a cooling effect as a Park Cooling Island (PCI), (Habibi, 2021, 15). The microclimate and energy consumption of buildings changes as air and surface temperatures decrease, which may increase relative humidity (Mohammad alinezhad, 2020, 2). Extensive vegetation helps reduce pollutants, improve thermal comfort, and regulate humidity (Rezaee et al., 2021, 10). In this regard, sustainable planting emphasizes the use of native plants with less need for care, chemical fertilizers, and irrigation (Fada'i Tamijani, 2022, 604).

In the Iranian garden, the pattern of tree placement has also been vital for humans (Habibi Khozani and Akbari, 2020, 13). With planting diversity as the main axis, we witness the sustainability of beneficial plants (Sheibani and Motlabi, 2014, 26). Planting plants with different growing and flowering times, such as the vanguard, is one of the initiatives of Iranian gardeners to show the precedence and delay of time. In contrast, the mere use of evergreen trees prevents the remembrance of time (Sheibani and Chamanara, 2012, 22). Given that two-thirds of Iran is hot and dry, the irrigation system affects the geometric design of the garden (Fadaei and Mofidi Shemirani, 2014, 35). In the northern regions of Iran, many of the physical types of gardens are formed based on water resources such as lakes and rivers (Rezazadeh and Heydarnetaj, 2017, 217). In gardens such as Abbasabad Behshahr, Khosrowabad Sanandaj, and El-Goli Tabriz, access to water resources made water central to the design of the gardens (Mansouri, 2005, 60). Some Iranian gardens, such as Abbasabad Behshahr, were built on naturally complex terrain with lakes, where efforts were made to preserve the natural state of the bed (Fig 1), (Haidernataj, 2017, 18). Given the unique characteristics of Iranian gardens, which utilize the intelligent integration of natural and cultural elements to create sustainable ecosystems, this model reflects the principles of sustainable development on a local and global scale. Therefore, examining the concepts of sustainable development and environmental sustainability as a framework for optimizing resources and reducing environmental impacts is an essential step towards preserving and improving the environment.

Sustainable development and environmental sustainability

Sustainable development1, the main slogan of the third millennium, arises from the impact of cities on the biosphere and human life (Qarkhloo and Hosseini, 163, 2006). It is a multifaceted concept that seeks to create a balance between economic and social growth and environmental protection (Klimovskikh et al., 2023, 9). According to the definition of the World Environment Committee and the United Nations in 1992, environmental sustainability is one of the pillars2 of sustainable development at the international level with the aim of preserving and maintaining valuable environmental resources in the long term, reducing environmental impacts for a better future for all (Shi et al, 2019, 12; Nasrabadi, 2023, 13). This pillar of sustainable development, based on key indicators in each geographical region, enables understanding the current state of the region's environment and the development of sustainable environmental programs and plans (Shams-ednini et al., 2019, 89). Development compatible with nature refers to issues such as reducing air, water, and soil pollution, using local and renewable materials, optimizing irrigation and designing to combat flooding (Fadaei and Mofidi Shemirani, 2021, 83), using plants for air conditioning, energy efficiency and productivity (Bahraini, 1997, 28), reducing the consumption of non-renewable resources, and recycling waste (Mohammad Alinezhad and Ghasemi Nasab, 2016, 21).

Since environmental issues have been recognized as the foundation and core of sustainable growth by international groups including the International Monetary Fund (Khan et al., 2024, 9790). Urban green spaces are among the most vital landscapes for improving urban well-being. Although these spaces can directly contribute to achieving environmental sustainability goals as "sustainable cities and communities" (Nasrabadi, 2023, 14). But there has never been a single, sustainable solution for the whole world. These solutions are tailored to the environmental and cultural situation of a country (Figure 1).

Research background

A review of the literature on the impact of Iranian gardens on environmental sustainability reveals a rich intersection of historical practices, ecological design, and contemporary applications. The Iranian garden is an important aspect of Iranian culture and heritage that plays an important role in promoting environmental sustainability through design principles and multifunctional applications (Table 1).

Table 1. Summary of studies on the Persian garden and the benefits received from it

Findings and Conclusions	Year	Researchers	Article Title
The geometric, physical structure, and elements of the gardens are compatible with the climate and reduce summer temperatures compared to the surrounding environment.	2008	Bamanian et al	Investigating the climate situation by examining the climate comfort situation in Jahannama Garden and Delgosha Garden, both examples, in three scales: urban climate, local climate, and microclimate.

[1] Sustainable Development: The term sustainable development originated from environmental movements (Sultani Moghaddas and Enzai, 2018).

[2] The three pillars of sustainable development were considered: economy (including efficient use of resources and promotion of green technologies), society (including addressing issues such as poverty, gender equality and social justice), and environment (reducing pollution, conserving resources and promoting renewable energy sources) (Shi et al., 2019; Al-Emran and Griffy-Brown, 2023). It seeks to establish social justice and economic prosperity through the effective use of natural and environmental resources (Hassanzadeh and Shirowzhan, 2022).

Findings and Conclusions	Year	Researchers	Article Title
The Persian garden is not limited to one form and includes spaces such as the city, square, cemetery, and school. Its reinterpretation in urban uses has advantages, including: restoring forgotten concepts, improving environmental conditions, adding green space, reducing stress, supporting sustainable development, reducing water and energy consumption, and creating shaded microclimates for climatic and visual comfort.	2024	Masnavi and Vahidzadegan	Recreating the concept and meaning of the Iranian garden in the Iranian-Islamic city garden
The integration of water corridors, wind, green spaces, and gardens, in addition to providing ecosystem services, affected ecological sustainability.	2021	Radaei et al	Ecological wisdom, a social–ecological approach to environmental planning with an emphasis on water resources: The case of Qanat Hydraulic Structure (QHS) in a desert city of Iran
In Iranian gardens, the geometric structure and physical elements create shaded and cool spots in the summer. The humidity under the cypress tree is up to 15% higher than near the water features. In the Delgosha garden, the density of citrus trees also helps reduce temperatures, thermal balance, and reduce daily and seasonal temperature fluctuations.	2021	Taghvaie et al	Investigating the role of shade in the Iranian garden, investigating the state of climatic comfort in the Jahannama and Delgosha gardens by examining the climate status of both samples in three scales of urban climate, local climate, and microclimate.
Understanding and examining the three systems of planting, water, and building placement in Iranian gardens shows that these systems effectively communicate with nature and work towards sustainable development and environmental sustainability. Water resource management, shade creation, air conditioning, use of renewable energy, and utilization of eco-friendly materials are important environmental aspects in the physical system of these gardens.	2016	Mohammad Alinezhad and Ghasemi Nasab	The physical system of the Iranian garden and environmental sustainability
The thermal comfort range in Bagh-e-Fin is 1.152°C higher than the historical context of Kashan, while the average temperature in Bagh-e-Fin is 11.3°C lower than the historical context of Kashan. Also, the relative humidity in Bagh-e-Fin is recorded to be 2% higher than the historical context.	2021	Fattahi et al	Title: Comparison of thermal comfort ranges of Bagh-e-Fin and the historical fabric of Kashan
Gardens in semi-arid and arid climates have a great impact on thermal comfort, and the planting system and vegetation cover are among the most important factors in creating comfort and environmental quality in Iranian gardens. There are major differences in thermal comfort of simulated vegetation models, which can be observed by changing the type, crown of trees, arrangement and number of trees. An examination of the average radiant temperature and the current thermal comfort conditions shows a significant relationship between these two indicators.	2021	Rezaei et al	The effect of plant planting system in Iranian gardens on thermal comfort of outdoor spaces, case study: Jahannama Garden, Shiraz
The broadest dimension in all gardens is the agricultural aspect; therefore, in addition to their cultural landscape and architectural heritage, historic gardens are urban agricultural sites due to their preservation of the agricultural dimension and accessible spaces.	2021	Khalilnezhad	Planning considerations, spatial characteristics, and principles of urban agricultural landscape design according to the Persian garden model

Findings and Conclusions	Year	Researchers	Article Title
The impact of Isfahan Garden Systems on the principles of landscape sustainability is as follows: water system 100%, planting system 71.5%, artificial system and materials 100%, and the average of these systems is about 90%. These results indicate the adaptation and adherence of natural systems and artificial elements to sustainable landscape patterns.	2022	Fadaei Tamijani	Reinterpretation of the Safavid Garden of Isfahan City Based on the Principles and Criteria of Landscape Sustainability

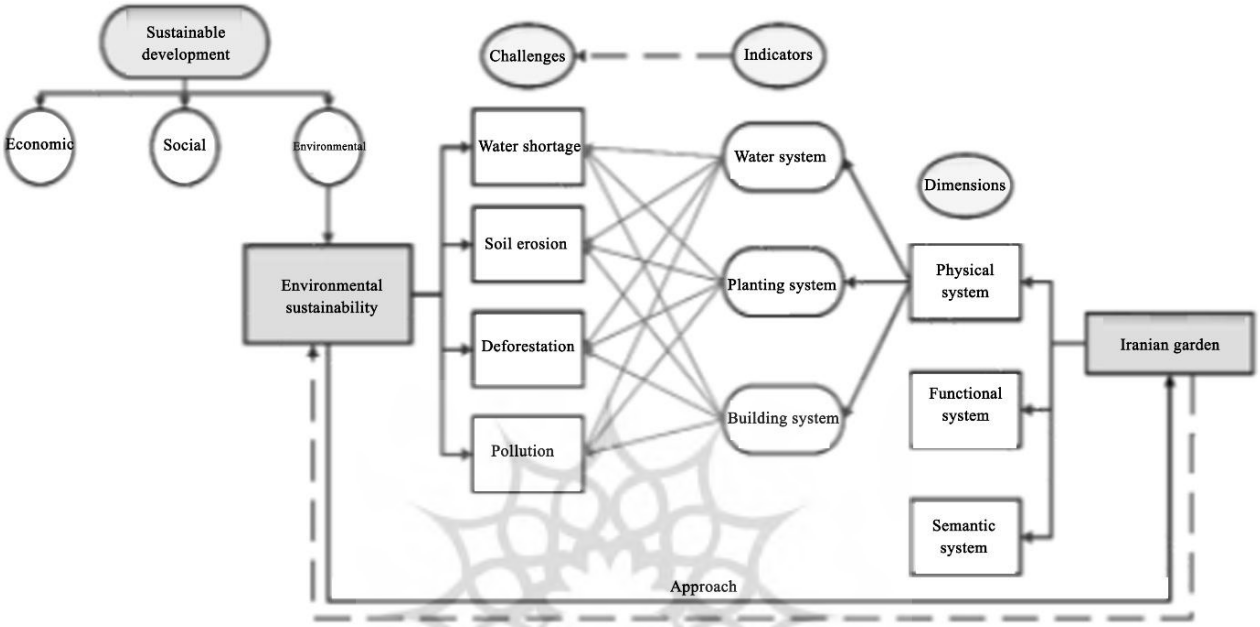

Figure 1. Conceptual research model

Materials and Methods

Scope of the Research Study

Behshahr city, located in the east of Mazandaran province, with an area of 2858 square kilometers, is located at an altitude of 50 meters above sea level and 14 kilometers from the sea. This city, located in the forested slopes of the Alborz Mountains, has long been one of the important cities of Iran due to its privileged natural and geographical location.

Among the valuable palaces and historical monuments of Behshahr city, the historical and recreational complex of Abbasabad Garden in Behshahr was considered as the study area of this research. This complex, with an area of about 600 hectares, includes parts such as a lake, dam, bathhouse, brick towers, palace, flower garden area, and paved roads. It was built in 1021 AH by order of Shah Abbas Safavi as a private resort of Shah Abbas Safavi in Mazandaran with the structure and function of a hunting garden (Sarfaraz and Azmoun, 2006, 43). This complex is completely intertwined with nature in the heart of dense forests due to its unique natural features and topography. Among its parts, we can mention the existence of a large triangular-shaped lake, a dam with an area of 10 hectares, a depth of 18 square meters, with a capacity of 600,000 cubic meters (Mu'ayr al-Mamalek, 2024, 33). The architectural plan of the garden was a combination of regular and organic geometry, and the design of the garden-bed was bilateral and in accordance with the two-sided slope of the land, which led to the creation of unique and unique views in this complex. With the passage of time and the abandonment of the garden after the era of Shah Abbas, only the lake, the remains of the four-arched arches and its brick towers remained.

In 1967, this complex, including the dam and the building in the middle of the lake, was registered on the list of national monuments. In the 1970s, archaeological excavations once again revealed buried parts of the garden, and in 2011, this valuable work was included in the UNESCO World Heritage List along with eight other Iranian gardens. However, since 2015, the transfer of management of the tourism sectors of this complex to

unrelated institutions has led to an intensification of the destruction of historical monuments. In August 2012, with the approval of the Behshahr master plan and the incorporation of this complex into the urban area, its management was transferred to the municipality without coordination with the cultural heritage.

These decisions, along with unauthorized activities and widespread destruction, pose a serious threat to the survival of this valuable heritage, and the continuation of this trend will lead to the risk of complete destruction of the Abbas-Abad complex (Haidernataj, 1402, 3), (Figures 2-5). This area, due to its natural, historical, and unique features, has been selected as a rich and valuable space for environmental sustainability analysis .The purpose of this research is to provide a comprehensive analysis of the relationship between the components of the garden's physical and environmental system, within this historical complex.

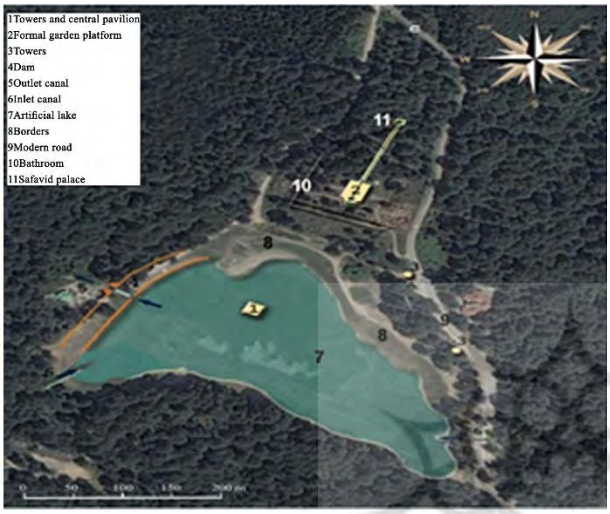

Fig. 3: Remaining buildings and equipment from the Abbasabad complex
(Adapted from: Dominic Brignoli et al., 2015, 43)

Fig 2: Abbasabad Garden, Lake and Historical Water Structures
(Source: Flytoday website, https://www.flytoday.ir)

Fig. 5: The path leading to the lake, By Authors

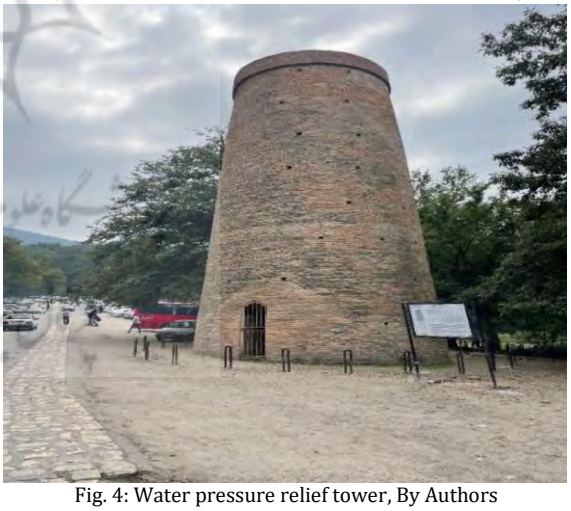

Fig. 4: Water pressure relief tower, By Authors

Fig. 7: Geometric section plan of Abbas Abad Behshahr complex
Source: Hamshahri website,
(https://www.hamshahrionline.ir/news/64621)

Fig. 6: Aerial view of the lake and Chartaqi
(Source: Khazarnama website, https://khazarnama.ir)

Research approach and analytical methods

The present study is designed with a descriptive-analytical approach and the use of qualitative and quantitative tools to investigate the physical system of the historical garden of Abbasabad, Behshahr. The descriptive-analytical approach is still one of the most important research methods in studying cultural heritage and environmental sustainability, especially in the field of Iranian gardens. For example, recent studies, including those by Kalimukikh et al. (2023), Nasrabadi et al. (2023), and Khan et al. (2024), have carefully examined various dimensions of architectural, cultural, and environmental components and analyzed the relationships between them, using a combination of qualitative and quantitative tools. This approach provides a comprehensive and multifaceted insight that is very effective in understanding the role of Iranian gardens in improving environmental quality and protecting natural resources.

Research information was collected from three main sources: first, library studies: including a review of historical, scientific, and specialized sources related to Abbasabad Garden and the principles of environmental sustainability; second, field observations: conducted to analyze the current state of the garden and document its key elements; and third, interviews and questionnaires: designed in a structured manner to collect the views of experts and stakeholders (tourists and indigenous people). The questionnaires are based on a Likert scale (strongly agree to strongly disagree) and have 37 items to assess the environmental challenges and capacities of the garden. They include questions in three main research areas:

1. Water system: Includes questions about water supply, water supply system quality, water transportation system efficiency, and water resources management. 2. Planting system: Includes questions about the condition of vegetation, biodiversity, the impact of pests and diseases, and soil conservation and erosion reduction. 3. Building system: Includes questions about the role of structures in forest protection, water resources management, and their impact on environmental sustainability.

In order to assess the validity of the questionnaire, the questions were shared with expert university professors in green space and landscape engineering, whose feedback indicated a high level of validity of the questionnaire, and corrections were made to improve the quality of the questions based on their opinions.

The research questionnaires were distributed in an illustrated format and with verbal explanations from the researchers at the Abbasabad Garden in Behshahr so that the participants1 would have a more accurate understanding of the concepts under study2. In addition, Cronbach's alpha coefficient was used to measure the reliability of the concepts and questions in the questionnaire.

[1] Specialized sections and questions that required expert opinions were examined using the opinions of experts in the fields of cultural heritage, green space, and landscape. In contrast, aesthetic aspects and general questions were extracted from the perspectives of ordinary people.

[2] This research was conducted in accordance with the ethical principles of the Declaration of Helsinki and the guidelines of the university's research ethics committee.

The coefficients indicate that the alpha coefficient of the items related to the dependent variables water index is 0.86, planting index is 0.89, building settlement system index is 0.88, and the independent variable environmental sustainability index is 0.84, which indicates the reliability and internal consistency of the items related to the different scales of the questionnaire (Table 2).

Table 2. Questionnaire reliability results based on Cronbach's alpha coefficient

Cronbach's alpha of the planting system

Reliability Statistics

Cronbach's Alpha	N of Items
0/894	9

Cronbach's alpha of the water system

Reliability Statistics

Cronbach's Alpha	N of Items
0/865	8

Cronbach's alpha for environmental sustainability

Reliability Statistics

Cronbach's Alpha	N of Items
0/845	8

Cronbach's alpha of the building system

Reliability Statistics

Cronbach's Alpha	N of Items
0/888	8

The collected data were analyzed using a combination of qualitative and quantitative methods. In the qualitative analysis, a systematic and phenomenological method was used. The content of the interviews was reviewed and the main themes were extracted. In the quantitative analysis, the questionnaire data were processed and statistically analyzed using SPSS software.

The statistical population of this study was tourists and officials of Behshahr city, and the Cochran formula was used to determine the sample size.

$$n=(E2\times (N-1)+Z2\times p\times (1-p))N\times Z2\times p\times (1-p)$$

Where: n = sample size, N = population size (168,769 people), Z = confidence interval value (1.96 for 95% confidence level), p = predicted population proportion (0.5 for the largest sample size), E = sampling error (0.05)

Using this formula, a sample size of 378 people was obtained, and with the aim of increasing the accuracy of the research results and analyses, 400 questionnaires were completed.

To analyze the collected data, this study used various statistical methods such as 1- Mean test: to examine differences and compare the average responses in different dimensions, 2- Frequency test: to analyze the distribution and frequency of responses and categorize data, 3- Spearman correlation test to examine the relationship between different variables, especially the relationship between environmental sustainability factors and components of the garden's physical system and 4- Multivariate regression: It was used to analyze the simultaneous effect of different variables on the dependent variable and examine the complex relationships between them. The research variables include 1- Independent variable: Variables that have a direct impact on environmental sustainability. These variables include the water system, planting system, and garden building system. , Dependent variable: Environmental sustainability, which has been evaluated through various components such as water resource conservation, deforestation, soil erosion reduction, and combating pollution.

Despite challenges such as limited access to some historical documents and the effects of climate change, this research attempts to provide a detailed and comprehensive analysis of the spatial system of Abbasabad Garden and clearly explain its role in achieving environmental sustainability goals.

Research findings

Demographic characteristics of respondents

According to the findings, 51% of the respondents were men and 49% were women. The age range of the respondents was above 25 years and in terms of education level, 20% were less than a cycle, 41% less than a bachelor's degree, 39% had a bachelor's degree and postgraduate education. Based on their occupation, 71% were freelancers and 29% were employees (Table 3).

Table 3. Statistical information of respondents

Percentage	Number	Group	Variable	Percentage	Number	Group	Variable
0	0	15-25 Years	Age	20%	80	Less than Secondary education	education
9%	36	35-26 Years		0	0	Less than a diploma	
40%	160	45-36 Years		41%	164	Less than a bachelor's degree	
20%	80	55-46 Years		39%	156	Bachelor's Degree and above	
31%	124	More than 56 Years		0	0	Unemployed	job
49%	196	Woman	Gender	0	0	Housewife	
51%	204	Man		71%	284	Freelance	
–	–	–		29%	116	Employee	

Average and standard deviation of indicators

The findings show that in most components, the average response is above 4 and there is significant concern about environmental issues. The following is an analysis of the various components and questions:

The water system (irrigation system) in Abbasabad Garden, with its measures, has effectively been able to control soil erosion (with a mean of 4.59 and a standard deviation of 0.49) and deforestation (with a mean of 4.29 and a standard deviation of 0.63).

It has also played a prominent role in reducing environmental pollution such as water, soil, and air pollution (with a mean of 4.20 and a standard deviation of 0.98) and has ensured the protection of these valuable resources by intelligently managing the garden's water resources (with a mean of 4 and a standard deviation of 0.94). The mean and standard deviation of this indicator are reported in Table 4.

Table 4. Comparison of average water system index components in Abbas Abad Garden, Behshahr

Sample	Standard Deviation	Average	Factor	Number of questions	Sample	Standard Deviation	Average	Factor	Number of questions
400	0.62	4.28	Deforestation	9	400	0.94	4	Water scarcity	5
400	0.63	4.29		10	400	0.89	3.98		6
400	1.18	4	Water, soil and air pollution	11	400	1.01	4	Soil erosion	7
400	0.98	4.20		12	400	0.49	4.59		8

The planting system, with its remarkable effectiveness, has been successful in controlling water, soil, and air pollution (with an average of 4.69 and a standard deviation of 0.46). Then, by reducing deforestation (with an average of 4.59 and a standard deviation of 0.49), it has played an important role in preserving natural resources, and in the next step, it has been able to reduce soil erosion (with an average of 4.39 and a standard deviation of 0.48).

In addition, it has also shown very good performance in controlling water deficit (with a mean of 4.20 and a standard deviation of 0.45) (Table 5).

Table 5. Comparison of average planting system index components in Abbas Abad Garden, Behshahr

Sample	Standard Deviation	Average	Factor	Number of questions	Sample	Standard Deviation	Average	Factor	Number of questions
400	0.50	4.49	Deforestation	17	400	0.45	4.20	Water scarcity	13
400	0.49	4.59		18	400	0.89	4.29		14
400	0.86	4.19	Water, soil and air pollution	19	400	0.63	4.29	Soil erosion	15
400	0.59	4.19		20	400	0.48	4.29		16
400	0.46	4.69		21	–	–	–	–	–

The building settlement system, with its various impacts on environmental fields, has played a significant role in controlling water shortages (with an average of 4.50 and a standard deviation of 0.92). It has also been effective in reducing soil erosion (with an average of 4.20 and a standard deviation of 1.25) and has been able to prevent further soil degradation.

This system has also performed reasonably well in controlling environmental pollution (with an average of 3.98 and a standard deviation of 1.01), although further action is needed in this area. Finally, this index has also had an impact on reducing deforestation (with a mean of 3.79 and a standard deviation of 0.97) and has prevented the reduction of garden vegetation (Table 6).

Table 6. Comparison of the average components of the building settlement system index in Abbas Abad Garden, Behshahr

Sample	Standard Deviation	Average	Factor	Number of questions	Sample	Standard Deviation	Average	Factor	Number of questions
400	0.97	3.79	Deforestation	26	400	1.25	3.90	Water scarcity	22
400	1.18	3.68		27	400	0.92	4.50		23
400	1.01	3.98	Water, soil and air pollution	28	400	1.25	4.20	Soil erosion	24
400۴۰۰	1.40	2.98		29	400	0.69	3.98		25

In the Iranian garden, different systems do not operate separately and uniaxially, but rather complement each other and are used for a common goal.

For example, in Abbasabad Garden, the middle building located in the center of the lake is based on a water breakwater that at first glance appears to be an architectural work, but in fact, the main function of the water breakwater was to reduce the pressure of the water entering the lake from the dam and prevent the dam from breaking.

This pavilion had a valve underneath it that transferred water to the garden and played a role in watering the trees in different parts of the garden. In addition, the brick towers around the garden, which were built as watchtowers, also played the role of water pressure breakers and helped direct and distribute water in different directions.

The Golbagh complex, which at first glance appears to be a recreational space with regular geometry, was actually designed to settle sediments and excess water from upstream springs in its lower part and direct the purified water to the lake and other parts of the garden to irrigate the trees. In this model, the system of establishing buildings in an Iranian garden is not limited to geometry and spatial design, but rather the type of materials used, the method of construction, and its relationship with other systems, especially the water system, play a fundamental role in maintaining the greenery and sustainability of the garden. For example, in areas where the cisterns carried water to other parts of the garden, this flow also carried moisture to the surrounding soil, allowing water to reach the roots of the plants. Therefore, the system of building placement in the Iranian garden not only helped to shape the space, but also, through its interaction with the water system and other systems, was a factor in the sustainability and greenery of the garden.

Bivariate analysis

In this study, the normality of the data was first assessed by examining Skewness and Kurtosis. The results showed that the values of skewness and kurtosis were within the acceptable range (between -3 and +3). Accordingly, the data distribution is assessed as normal. Furthermore, given the sample size of this study, which is equal to 378 people, and by citing the central limit theorem, the assumption of normality of the data distribution is further strengthened. This theorem states that as the sample size increases to sufficiently large values (usually n ≥ 30), the distribution of the sample means tends towards a normal distribution, regardless of the shape of the initial statistical population distribution.Therefore, the use of parametric statistical methods in this study is based on empirical evidence and valid statistical principles and has sufficient scientific validity (Table 7).

Table 7. Statistical distribution of indicators (skewness and kurtosis)

	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
K1- Water	400	-1/29	0/98	0/0000	0/73091	0/534	-0/378	0/122	-0/862	0/243
K2- Planting	400	-1/31	0/96	0/0000	0/75951	0/577	-0/217	0/122	-1/316	0/243
K3- Building	400	-1/79	1/12	0/0000	0/76792	0/590	-0/959	0/122	0/631	0/243
K4- Sustainability	400	-1/70	1/01	0/0000	0/67733	0/459	-0/740	0/122	0/385	0/243
Valid N (listwise)	400									

Spearman's test

Although the data in this study were normally distributed, Spearman's test1 was used to examine the correlation between the indicators. This choice was made especially because of Spearman's test's ability to

[1] Spearman's rank correlation: weak correlation > 0.3, weak correlation 0.3-0.5, moderate correlation 0.5-0.7, strong correlation 0.7-0.9, very strong correlation > 0.9 (Hinkle, Wiersma, & Jurs. 2003) / * Significant at the 0.01 level / * Significant at the 0.05 level / ns: Not significant

identify nonlinear and rank relationships between variables, as well as its flexibility against outliers and abnormal values.

Despite the normality of the data, Spearman's test was used as a valid and conservative tool to improve the accuracy of the correlation analysis and to accurately simulate the results of more complex relationships. The results of the Spearman test were evaluated in two stages:

In the first stage, correlation analysis was conducted between the three main indicators of the physical system, including water system, planting system, and building establishment system. The results indicate positive and significant correlations between these three indicators. In particular, there are strong and significant relationships between water and planting (correlation coefficient 0.828), as well as water and building establishment (correlation coefficient 0.775) ($p < 0.001$).

These relationships show that the different components of the garden physical system interact with each other in a reciprocal and effective manner, and changes in one indicator can have significant effects on other indicators. In addition, the correlation between planting and building placement is also significant, with a correlation coefficient of 0.552 ($p < 0.001$), which also indicates a positive and relatively strong relationship (Table 4).

In the second stage, the results of examining the correlation between the physical system indicators and environmental sustainability show that there are significant relationships between these indicators. In particular, the correlation between the water system and environmental sustainability is negative and significant at -0.244 ($p < 0.001$), indicating that the more problems there are in the garden's water system, the less environmental sustainability will be.

Also, the relationship between planting system and environmental sustainability is also negative and significant at -0.501 ($p < 0.001$), which indicates that problems in the planting system can lead to a decrease in environmental sustainability in the garden. In contrast, the building system has a positive and significant relationship with environmental sustainability at 0.247 ($p < 0.001$), which indicates that improving the condition of the building system can have positive effects on environmental sustainability in the garden.

These results emphasize that to improve environmental sustainability in the existing garden, it is essential to pay attention to improving and optimizing the status of various indicators of the garden's physical system (Table 8).

Table 8. Spearman correlation between the garden physical system indicators with each other, then each of them with the environmental sustainability index

Variable (index)		Water system	Planting system	Building settlement system	Environmental sustainability
Water system	Correlation coefficient	–	0.828**	0.775**	–0.244**
	Significance	ns	0.001	0.001	0.001
Planting system	Correlation coefficient	0.828**	–	0.552**	–0.501**
	Significance	0.001	ns	0.001	0.001
Building settlement system	Correlation coefficient	0.775**	0.552**	–	0.247**
	Significance	0.001	0.001	ns	0.001
Environmental sustainability	Correlation coefficient	-0.244**	-0.501**	0.247**	–
	Significance	0.001	0.001	0.001	ns

Multivariate data analysis using regression approach

To analyze complex and simultaneous relationships between several independent variables and a dependent variable, multiple regression was used. This statistical method is particularly useful when the goal

is to examine the simultaneous effects of several independent variables (in this study, various indicators of the physical system) on a dependent variable (environmental sustainability).

In this study, three indicators of water system, planting system and building system were considered as independent variables and environmental sustainability was considered as dependent variable. This model was used to simulate and analyze the simultaneous effects of different indicators of the physical system on environmental sustainability and to identify the different dimensions of these effects. The results of multivariate regression analysis are as follows:

The results of multivariate regression analysis indicate significant and different relationships between these indicators and environmental sustainability. First, the water system with unstandardized coefficients of -0.226 and standardized coefficients of -0.243 shows a significant negative effect on environmental sustainability (p = 0.041), which means that the problems in the irrigation system and water resources management cause a decrease in environmental sustainability. In addition, the planting system has a significant negative effect on environmental sustainability with unstandardized coefficients of -0.428 and standardized coefficients of -0.480 (p = 0.001). This indicates that problems related to plants in the garden can negatively affect environmental sustainability. In contrast, the system of building placement with non-standard coefficients of 0.460 and standard coefficients of 0.522 has a positive and significant effect on environmental sustainability (p = 0.001). This result shows that optimizing the placement of buildings in the garden can positively affect environmental sustainability.

Overall, the analyses show that the building system has the greatest positive impact on environmental sustainability, while the water system and planting system have lesser impacts on environmental sustainability. These results emphasize the importance of improving irrigation systems and proper plant selection, and suggest that attention to reforms in these two areas is essential to improve environmental sustainability in existing gardens (Table 9).

Table 9. Results of the multivariate regression test

Variable	Model	Unstandardized Coefficients (B)	Standard Error (Std. Error)	Standardized Coefficients (Beta)	t-Value	Significance Level (Sig)
Dependent variable	Environmental sustainability	-7.120	0.028	–	0.000	1.000
Independent variable	water system	-0.226	0.110	-0.243	-2.050	0.041
	planting system	-0.428	0.079	-0.480	-5.422	0.001
	Building establishment system	0.460	0.063	0.522	7.272	0.001

Durbin– Watson test

To assess the presence of autocorrelation in the regression model errors, the Durbin-Watson test was used, and the value obtained was 1.464, which is relatively close to 1.5.

Since the valid and acceptable range for this index is usually between 1.5 and 2.5, the resulting value indicates the presence of positive autocorrelation in the errors. However, given that this value is not significantly far from the lower limit of the range and is still within an acceptable range and at a relatively appropriate level, it cannot be considered as a threat to the independence of the errors and the accuracy of the model.

As a result, this amount of autocorrelation is at a level that will not have a significant negative impact on the validity and accuracy of the regression analysis results (Table 10).

Table 10. Watson-Durbin test

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0/565[a]	0/319	0/314	0/56109	1/464
a. Predictors: (Constant), K3, K2, K1					
b. Dependent Variable: K4					

Examining collinearity between independent variables and evaluating its impact on the regression model

To assess the collinearity between the independent variables and ensure that they do not have an adverse effect on the regression model, the Variance Inflation Factor and Tolerance indices were calculated. The results showed that the VIF values for the independent variables were 8.197 for K1, 4.557 for K2, and 2.992 for K3, respectively.

Since the VIF values are all less than the threshold of 10, it can be concluded that the collinearity between the independent variables is at an acceptable level and these values indicate the absence of severe and problematic collinearity in the regression model. In addition, the tolerance values were obtained as 0.122, 0.219, and 0.334, respectively, which are also above the threshold of 0.1, meaning that there is no severe and worrying collinearity between the independent variables. Based on these results, it can be concluded that the independent variables of the model will not have a negative impact on the validity and accuracy of the regression model and the existing collinearity is at an acceptable level (Table 11).

Table 11. Evaluation of collinearity between independent variables using VIF and tolerance indices

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7/120E-16	0/028		0/000	1/000		
	K1	-0/226	0/110	-0/243	-2/050	0/041	0/122	8/197
	K2	-0/428	0/079	-0/480	-5/422	0/000	0/219	4/557
	K3	0/460	0/063	0/522	7/272	0/000	0/334	2/992

a. Dependent Variable: K4

Discussion and Conclusions:

Abbasabad Garden in Behshahr is currently facing some environmental challenges such as the reduction of the lake water level, the destruction of part of the tree cover, the encroachment on the natural forest boundary, and environmental pollution that has affected the historical gardens.

But it remains a unique example of the combination of geometric order and free nature, with regular axes, stepped terracing, and an engineered lake, demonstrating the harmony of architecture and the natural environment. With its intelligent water management in the past and dynamic landscape design, this garden is a leading model of sustainability and beauty in Iranian gardening and is the most important non-desert garden in Iran.

The physical system of this indicator pattern can be analyzed as follows:

Water system

Abbasabad Garden consists of various parts such as the lake, dam, four-arched tower, and the Gol Bagh or Chahar Bagh complex. One of the most important parts of the Abbasabad complex that had guards assigned to guard it was the Gol Bagh. This part was built 600 meters away from the main garden with an area of approximately 3500 square meters as a water distribution station in the Abbasabad complex. Originally, the land was sloping and was leveled to become a water station. Part of it is a sunken pond where water was previously purified and directed to the garden through clay pipes called tanboshehs. The lake is actually a huge reservoir whose water is supplied from the spring water tank and from melting snow and precipitation through clay tanboshehs. In the center of the lake, we see a strong arch made of brick and mortar, the only way to connect to it is a wooden bridge in the north of the building and has engineering purposes. During high water, when the Abbasabad Dam is likely to break, the arch is used through a network of gates located in its lower part to control the water pressure (breakwater) and discharge it to a place 200 meters away from the dam and downstream lands such as the villages of Al-Tapa, Saro, and Shahgileh. This building was submerged when the dam was filled, and

only its roof is visible. The lake is surrounded by natural surroundings on three sides, and a dam was built on its northern side. Abbasabad Dam was built to store water for agricultural purposes and flood control, and the materials used in this system are bricks, stones, and mortar, which effectively withstand hydrostatic pressures and prevent water from freezing. According to the survey, some parts of the dam were previously built of lime mortar, which prevented the growth of the plant Loya, which grows in all the dams in Mazandaran. The Abbas-Abad dam was complemented by brick towers1 in this complex, which acted as hydraulic pressure breakers to control sudden water pressures and prevent damage to the irrigation system. They regulate the flow of water during times of drought or high water levels, play a role in the leaching process, and settle suspended particles so that more purified water can be transferred to the irrigation system. Overall, these towers, with their multiple functions, played a fundamental role in optimizing the use of water resources and maintaining the sustainability of the irrigation system. Today, there are many concerns about the water system of Abbasabad, because the irrigation infrastructure is not managed properly, which has caused the destruction of a large part of this huge system. This garden does not naturally need irrigation, but it plays a significant role in supplying water to the agricultural areas of the surrounding villages. Failure to pay attention to this system will reduce the environmental sustainability of the region. This sector appears to be in need of urgent improvement and reconstruction (Table 12).

Table 12. Impacts of water system[2] sub-components on environmental sustainability

Water System	System characteristics	Relationship to environmental sustainability
Brick Towers	Hydraulic pressure relief valves for water pressure control	Regulating water pressure, preventing damage to the irrigation system, purifying water, and assisting in the settling process of suspended particles.
Gol Bagh (Water Distribution Station)	Water distribution through clay pipes to the garden and surrounding areas	Uniform water distribution without the need for chemicals, helping to purify water and reduce resource consumption.
Lake	Large reservoir of water supplied from springs, snow, and rainfall	Providing water for agriculture and drinking water, managing water resources sustainably
Four-arched or Chartaghi	Valve systems for releasing water pressure in the dam	Protecting the dam from sudden pressures, preventing damage to the dam, using sustainable engineering principles in protecting natural resources.
Underground Irrigation System	Using clay pipes (tanbousheh) to transport water	Reducing the need for energy-consuming irrigation systems, using natural materials to reduce negative impacts on the environment.
Plant and Ecosystem Protection	Optimal irrigation systems for natural plant growth	Preserving and improving biodiversity, preventing the use of chemicals and negative effects on soil and plants.
Connection with Nature and Sustainable Design	Design without fences and artificial borders	Maintaining connection with nature, preventing the creation of barriers to ecosystems, and supporting biodiversity.

planting system

Abbasabad was formed in the Hyrcanian forest zone. This area has a high biodiversity in terms of flora and fauna. However, there is no precise information available on a specific pattern of planting or the use of different plant species from the substrate during the Safavid period.

According to field observations by the researchers of this article, most of the trees in this garden include Ulmus minor, Alnus subcordata, Quercus, as well as various shrub species such as Mespilus germanica, Crataegus, Rubus fruticosus, and Punica granatum.

Due to their geographical location in the heart of a forested area, the trees of Abbas Abad naturally do not need irrigation systems and benefit from natural resources such as rainfall and water flows in the area. This allows the garden to continue its life without the need for artificial irrigation. Tree roots penetrate deep into the soil, preventing soil movement due to heavy rainfall and local winds, increasing the cohesion of the soil structure, and preventing the destruction and erosion of soil resources. Also, by absorbing and storing water in the soil, it prevents rapid evaporation of water from the soil surface and

[1] Two brick towers are located in the northeast of the garden, built with materials such as brick and mortar, with a height of 14 meters, a base of 7 meters, and a distance of 175 meters from each other.

[2] The presence of water in the garden means only using water in the garden for garden purposes, but when we use the term water system, it means that there are parts that complement each other and create a single system due to the role of each on the other (Shahcheraghi, 2016).

maintains moisture in the lower layers of the soil. It helps preserve vegetation cover against short-term and long-term droughts, prevents water problems in the region, and plays an important role in improving the hydrological conditions of the region. Abbasabad trees, with their different crown and aerial parts, absorb carbon dioxide and produce oxygen through the process of photosynthesis, reducing air pollution. In urban and semi-urban areas that suffer from industrial and traffic pollution, they can play an effective role in improving the quality of life.

However, the garden faces several threats such as timber smuggling, pests, disease and fire. One of the biggest threats is illegal logging, which has damaged the natural ecosystem of the area and has disrupted its biological balance to some extent. Also, plant pests and diseases have continuously damaged the vegetation and increased the rate of forest destruction.

Among the rare plant species in this garden is Castanea sativa. This tree, which is between 370 and 400 years old, is the only existing tree in the Abbasabad forest and eastern Mazandaran. It is located in the northeast of the garden and 50 meters from the northern gate. Unfortunately, this species is in danger of extinction due to disease, natural factors, and human interference.

Natural or intentional fires are also considered a serious threat to this forest area, which can spread rapidly during dry seasons and can destroy many trees and vegetation, leading to the destruction of vegetation and a reduction in its positive effects in maintaining environmental sustainability. Trees, which play a vital role in carbon sequestration and oxygen production, are particularly under threat. Reforestation through planting resilient trees and better forest conservation management can play an important role in promoting the environmental sustainability of the garden. Overall, garden trees, with their natural characteristics, play a vital role in preserving natural resources such as soil, air, and water, and help to maintain this ecosystem. Protecting these resources is essential not only to maintain biodiversity, but also to combat environmental threats such as climate change and environmental degradation (Table 13).

Table 13. Effects of planting systems[1] on environmental sustainability

Abbasabad Planting System.	System Characteristics.	Impacts on Environmental Sustainability
Water resources management	Exploitation of natural water resources such as rainfall and groundwater flows without the need for artificial irrigation.	-Reducing pressure on water resources and preventing water waste -Preserving and optimizing the use of natural water resources -Reducing the need for artificial irrigation, which reduces energy consumption and water resources.
Preserving and enhancing biodiversity	Using native and resistant species (such as oak, elm, alder) that help create balanced and sustainable ecosystems.	-Enhancing biodiversity at the plant and animal levels -Creating diverse habitats for animal species -Preventing species extinction and preserving the region's genetic diversity
Soil erosion control	Using tree roots, which increase the cohesion and stability of the soil structure and prevent soil movement.	-Prevent soil erosion and maintain soil structure -Reduce runoff and preserve groundwater -Strengthen the stability of soil resources against heavy rainfall and local winds
Improve air quality	The process of photosynthesis in trees, which absorbs carbon dioxide and produces oxygen, also plays an important role in reducing traffic and industrial pollution.	-Reduce air pollution and improve air quality by absorbing pollutants -Reduce greenhouse gases (especially carbon dioxide) and increase oxygen production -Help improve the health of urban ecosystems

[1] Despite many Iranian gardens being based on a regular and designed geometry, the planting system of Abbasabad Garden follows an organic pattern and is in harmony with nature. This garden is formed in the heart of a forest and, instead of following common Iranian garden designs, it has adapted to the natural topography of the land and the characteristics of the forest ecosystem of the region. Its trees and vegetation have grown more naturally and with minimal human intervention, so the garden seems like a continuous part of the forest rather than a perfectly designed space.

Conserving water resources and improving hydrology	Trees help absorb and store surface and subsurface water and reduce evaporation.	-Maintaining soil moisture and preventing periodic droughts. -Improving the hydrological situation and facilitating natural water flows. -Controlling groundwater levels and preventing soil erosion.
Protection of rare plant species	Identifying and protecting rare trees such as chestnuts and other native plant species in the region.	-Maintaining genetic diversity and protecting rare species -Preventing the extinction of native and rare species -Role in maintaining biodiversity and combating environmental threats such as climate change
Reducing environmental threats and restoring ecosystems	Protecting and managing pests and diseases, preventing illegal logging, and combating fires.	-Protecting the forest ecosystem against human and natural threats -Regenerating vegetation and strengthening ecological capabilities -Reducing the negative impacts of fires and other environmental crises

Building system

The buildings in the garden include a bathhouse, a mill, a middle pavilion, and a Safavid palace. The Abbasabad bathhouse is located next to the main palace and the paved area of the garden. The dimensions of this building are small but it has the traditional characteristics of past baths, and it is currently collapsing.

One of the interesting points of this bath is its water supply method. Water entered the complex from the eastern part of the bath building through clay pipes located inside the walls of the bath building, and after passing through the northern side of the bath wall, it entered the western side and filled the hot water tank. Then, after being heated through clay pipes (tanbousheh), the water in the tank filled the other existing pools in the hot tub.

The method of supplying cold water to the aforementioned bathhouse building is the same as hot water. Thus, cold water, through clay pipes, after passing through the eastern side of the bathhouse, filled a basin upstream (outside the bathhouse building) through clay pipes (tanbousheh) and filled the basins in the head and hot room spaces.

Also, the smoke outlet was completely wrapped under the floor of the bath so that the heat of the smoke was completely absorbed into the space and not wasted. It was made of materials such as brick, mortar, and tile, and the bath's ceiling was dome-shaped.

Other buildings in the complex include a water mill. The mill was built approximately 1.5 kilometers south of the garden between two rivers. The main materials used in the structure are stone, brick, and mortar. The bricks used in the mill are 5×26×26 centimeters in size, and access to the mill is via a paved road.

The way the above structure works is that water is directed through a covered canal to an open brick canal 100 meters long, then moves towards the mill wheel with a fairly suitable slope, causing the wheel blades to move.

Safavid engineers made the most of water energy by building a water mill at the site. The Safavid palace was also built north of Abbasabad Garden, on top of a mountain 2 kilometers from the garden and facing the lake. Today, its remains have been found, which historians consider a summer palace, built of brick and mortar like the others.

The middle pavilion above the four-arched pavilion is one of the other buildings in this complex, and its material has been described by researchers like the other buildings, but at present this pavilion has been destroyed and no trace of it is visible. It is clearly evident that the buildings in the garden are made of brick and mortar, which is incompatible with the temperate and humid climate of the north;

However, lime was used in the construction of the brick mortar to increase resistance to moisture, but the rate of destruction of this building was much higher than that of buildings in desert areas (Table 14).

Table 14. Impacts of building system subassemblies on environmental sustainability[1]

Abbasabad Building System	System Features	Impacts on Environmental Sustainability
Abbasabad Bath	Water supply system with clay pipes for hot and cold water, heating by absorbing heat from hot water tanks located in the space between the bathroom wall and floor, domed ceiling, building material made of bricks, mortar and tiles	Optimal use of water and energy resources, prevention of heat and energy waste through advanced heating systems, moisture-resistant native materials
Water Mill	Exploitation of water energy to move wheels, stone materials, bricks and mortar, irrigation system with covered and open canals	Using renewable energy to produce mechanical energy and reduce dependence on fossil fuels, optimize water consumption, and reduce pollution.
Safavid Palace	Location on top of the mountain for natural ventilation, brick and mortar materials, summer palace with proper design to reduce heat and improve ventilation	Climate-friendly design, using natural ventilation to cool the space and reducing the need for mechanical ventilation and cooling systems
Middle Pavilion	Brick and mortar structure, natural ventilation and placement on top of a four-arched roof	Utilizing natural ventilation to control temperature and optimize climate conditions, creating a sustainable space in harmony with the natural environment.
Building Materials (Bricks, Mortar, and Lime)	The use of bricks, mortar, and lime in building construction, especially lime to increase resistance to moisture.	Reducing dependence on non-recyclable materials and using natural materials that have less negative impacts on the environment, increasing durability
Damage from Building Destruction	Erosion and destruction of some structures, loss of native materials (bricks, stones), and damage to the region's ecosystem	Waste of natural resources, damage to ecosystems and reduction of biodiversity, increased waste production and destruction of the local environment

Compared to the previous two systems, the building placement system, as one of the more effective components in maintaining the environmental sustainability of Abbasabad Garden, has received more positive comments from users.

Because a number of buildings in this section were considered as protective factors for the forest and its irrigation system, they can play a greater role in protecting the Abbasabad forest complex by preventing timber smuggling, managing pests, controlling the garden's water sector, and further managing the complex.

The difference in respondents' opinions can be explained as the Abbasabad complex is layered and has different levels; therefore, the difference in responses among different groups who have different levels of knowledge of the garden can stem from the garden being layered.

The following suggestions are derived from a deep reflection on the research findings and a thoughtful look at the three key systems of water, planting, and building placement in Abbasabad Garden. Inspired by ancient wisdom in Persian garden design, these measures take steps to optimize the use of natural resources and revive the unique values of this precious heritage, with the aim of preserving its historical splendor and enhancing environmental sustainability.

[1] The data in this table is derived from field studies and interviews with cultural heritage experts, and in the process of collecting them, all effective environmental variables at the time of harvesting have been carefully evaluated.

Water System :

*Given the importance of Abbasabad Dam and its role in water regulation, it is essential to repair the dam walls with indigenous materials such as mortar and develop pressure control mechanisms to prevent dam failure (Cited in the Florence Charter1, 1981, Article 92).

*Pipelines play a key role in water transport. Examining their current condition and replacing damaged pipes or redesigning existing systems can help reduce water loss (Cited in the Florence Charter, 1981, Article 9).

*Given the possibility of contamination of water resources by visitors or human activities, the installation of natural filtration systems using water lilies or natural filter rocks is recommended to control water quality (Cited in the Florence Charter, 1981, Article 23).

*Given the presence of the Abbasabad Dam and the old water canal system, it is suggested that these systems be fundamentally renovated and combined with modern technologies such as water sensors and drip irrigation to prevent waste of resources (Cited in the Florence Charter, 1981, Article 9).

Planting system:

*Strengthening the genetic banks of orchard trees is essential to preserve existing species and combat threats such as pests and diseases, and diseased trees require treatment (Cited in the Florence Charter, 1981, Article 114).

*It is recommended to use GIS-based planting systems to intelligently identify suitable areas for planting any plant species (Cited in the Florence Charter, 1981, Articles 11 and 9).

*Preventing illegal logging and developing forest monitoring programs are essential to preserve vegetation cover. At the same time, planting fast-growing native species is recommended for forest restoration, and newly replanted trees require increased care and maintenance (Citing the Law on the Preservation and Expansion of Green Space and the Prevention of Uncontrolled Cutting of Trees, 1973, Article 15; Florence Charter, 1981, Article 2).

Building Settlement System:

*Materials such as brick, stone, and mortar that are compatible with climatic conditions should be used in the restoration of the buildings of the Abbas Abad Historical Garden. This will help preserve the historical identity of the garden, in addition to reducing energy consumption (Cited in the Florence Charter, 1981, Article 9).

[1] Florence Charter: An international document developed in 1981 by the International Council on Monuments and Sites (ICOMOS), which considers historic gardens not merely green spaces, but living and dynamic works that have been shaped by the interaction of history, art, and science.

This charter emphasizes preserving the authenticity and identity of gardens, conscious restoration, and avoiding any unnecessary changes, and considers them valuable treasures that find meaning in an inextricable link with their architecture, vegetation, and water structures. Protecting this heritage requires not only sustainable management and ongoing care, but also documentation, education, and awareness-raising. This charter is recognized as one of the world's reference documents in the field of gardens and historic sites.

[2] Article 9 of the Florence Charter emphasizes the identification and cataloguing of historic gardens as a fundamental step in the protection of this valuable heritage. According to this article, historic gardens in need of maintenance, conservation, restoration and, in certain cases, major reconstruction are recommended. Also, preserving the authenticity of the design and its various elements, including vegetation, architectural decorations, and non-living structures, is an undeniable necessity so that the historical and aesthetic identity of these spaces remains sustainable for future generations.

[3] Article 2 of the Charter of Florence states that the historic garden is an architectural composition whose elements, mainly related to gardening, are living and dynamic; therefore, these elements are mortal and replaceable. Thus, the garden's appearance reflects a constant balance between the cycle of the seasons, natural changes, and the will of the artist and gardener to preserve its identity—a balance that lies between the ceaseless movement of nature and the human effort to immortalize beauty.

[4] Article 11 of the Florence Charter (1981) emphasizes the preservation of the original vegetation of historic gardens and states that the selection of new species should be based on compatibility with the original plant composition and the originality of the garden. It also indicates that any changes to the vegetation should be made taking into account the historical and aesthetic characteristics of the garden, in such a way as to preserve its identity and coherence.

[5] This law was passed to preserve the urban environment, prevent the reduction of vegetation, and combat illegal cutting of trees, and is considered one of the most important regulations related to the preservation of green space in Iran.

*Creating pavilions and platforms in keeping with the historical authenticity of the garden, around the garden, which, in addition to attracting tourists, will provide the opportunity to hold cultural and educational events (Cited to the Florence Charter, 1981, Article 10).

*Developing educational spaces in the form of environmental museums and providing information about the planting system, water, and historical structures of the garden (Citing Guidelines on Education in the Conservation of Monuments, Collections and Sites, 19931).

*Reconstruction of brick towers and bridges, observing restoration principles, in order to maintain the strength and functionality of historical and cultural structures (Cited to the Florence Charter, 1981, Articles 9 and 122).

*Developing fundraising programs for conservation projects through sustainable tourism and creating temporary local stores for economic sustainability (Citing the Cultural Tourism Charter, 1999, Articles 33 and 44).

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[1] The General Assembly of the International Council on Monuments and Sites, ICOMOS, at its tenth session in Colombo, Sri Lanka, from July 30 to August 7, 1993.

[2] Article 12 of the Florence Charter (1981) emphasizes that the protection of historic gardens includes not only the vegetation, but also all architectural elements, water structures, sculptures, decorations, and associated spaces. This article emphasizes that all components of the garden, both living and non-living, are part of a single whole and must be maintained, restored, and revitalized using scientific and principled methods.

[3] Revenue from cultural tourism should be used directly for the conservation, management and promotion of public awareness of historical sites. Financing through tourism should not cause damage to the natural and cultural environment, but should be in line with the preservation and sustainability of this heritage. Also, tourism policies should be formulated in a way that provides sustainable funding for conservation projects and prevents destruction caused by tourism activities.

[4] Local communities should play an active role in the planning, development and management of cultural tourism in order to directly benefit from its benefits. Tourism development should not lead to the weakening of the traditions, lifestyles or economic independence of local communities, but should help to strengthen them. In this regard, tourism should create equitable economic opportunities for local communities, including employment in tourism-related sectors, support for local products, and the development of sustainable tourism services that help preserve the region's culture and environment.

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