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Research Article

The Development of Geotourism in the Akhlamed Valley in Eastern Iran Through the Evaluation of Geomorphosites

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Abstract

Geotourism or land tourism is considered a relatively new concept in tourism industry that has gained a considerable growth and attention in the recent decade. Geotourism can have the most harmony with sustainable development and all economic, cultural, social and environmental dimensions. The present paper aims to study an attractive geomorphotourism site around the city of Mashhad. To this end, several Geomorphosites resulting from the erosion process were selected for tourism development and their capabilities were evaluated. To evaluate geomorphotourism development potentials of the study area, Pereira method was used and field data collection and evaluation were conducted applying a Geographical Information System (GIS). By evaluating the scientific index of the selected Geomorphosites, it was found that dolines obtained the highest score followed by rock walls. For the complementary index, the highest score belongs to the rock walls and Akhlamad main waterfall, respectively. For the protection index, dolines, rock walls, and karst valleys had the highest scores, respectively. For the usage index, rock walls obtained the highest score followed by Akhlamad River. Scientific findings of the documentary and field studies showed that Akhlamad has significant potential for adventure and educational tourism, and mountain and winter sports due to the development of morphological-hydrological landscapes. The results also indicated that to make optimal use of the geotourism potential of Akhlamad, should be considered.

Keywords

Geomorphotourism, GIS, Pereira Evaluation Method, Akhlamad, Geotourism Sites

1. Introduction

Due to its unique geological structure, Iran has a special capability in the field of geotourism. The development of this sector can contribute significantly to the protection of the land and to the development of local communities on cultural, economic, and social levels. There are several items that must be addressed by the Researchers, scientific and research centers and tourism ministry of Iran, including identifying geotourism destinations, addressing geopark issues and solutions, diversifying geotourism activities, and developing education and human resources for tourism. Geotourism is a

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branch of the tourism industry that focuses on geological, geomorphological, and mining phenomena and attractions in tourism.

Geotourism is fundamentally a geosite-based activity. Modern geotourism was first defined by Hose [14]. Early geotourism was strictly defined as geological and geomorphological tourism [15-17, 1, 34] and was later determined to be a form of nature tourism focused on geological sites [32, 11] with emphasis on the "geological" element and geo-interpretation [18-21, 33].

Geotourism or land tourism is considered a relatively new concept in tourism industry that has gained a considerable growth and attention in the recent decade. Geotourism has defined boundaries that geological tourism is on its spotlight [8] and surveys the problems and complications associated with the land, geomorphologic situation, tectonic phenomena as well as their tourism capacity. In Newsome and Dowling words, Geotourism is a part of land associated with geology, geomorphology and natural landscape resources as well as available forms on the land surface, fossil-containing layers, rocks and minerals according with the emphasis on understanding the underlying and shaping processes of these complications [8].

It should be said that, Geomorphosites, geomorphoheritage, and geomorphic tourism are commonplace concepts in many nations. The value of the Geomorphosites has been introduced and defined both to communities and to scientists from other fields in an inappropriate manner [9], and a ttention to geotourism is developing worldwide [32, 33].

Geotourism addresses not only specialists and experts in geology and geomorphology, but also ordinary tourists and all nature lovers who get acquainted with the origins and importance of geology while visiting geological phenomena during tourism activities. Following the development of geoparks, geotourism was recognized by UNESCO (United Nations Educational, Scientific and Cultural Organization) as a young industry in 2002. Nowadays, many Geomorphosites have received the attention of tourist planners for the visit and use in adventure and health tourism, and some packages combining different types of tourism have been created. Many salt mines, hot springs, ponds and sludge basins, karst phenomena, sandy and rocky beaches, mineral springs, geysers, etc. have tourist and economic attractions, in addition to geomorphological attractions. Geosite and Geomorphosite are two new concepts in tourism literature that have been introduced in the geographical and tourism literature with an emphasis on determining special and valuable tourist places [22]. During the last decades, some attempts were made to evaluate the quality of geomorphological heritage and the capabilities of different tourism Geomorphosites [38]. Generally, geosites are places with interesting geological and geomorphological forms and processes in which tourism infrastructures have been created [12]. Similarly, Geomorphosites are areas and landforms of particular geomorphological interest with scientific, ecological, cultural, aesthetic, and economic values for tourist perception and exploitation [35]. They are considered as one of the important elements of natural protected areas with natural and cultural values and are, in general, a special natural landscape that in itself and in combination with cultural, historical, and ecological heritages have potential for sustainable tourism (Shayan *et al.*, 2010). Scientists studied the value of geomorphological units from three different perspectives: 1) ecosystems and natural habitats, 2) specific geomorphological landscapes, and 3) natural value in the natural environment. At present, the first one is emphasized leading to significant degradation of geomorphological forms and geological landscapes, which are valuable phenomena for protection, research, and management. The second one defines Geomorphosites as cultural and educational landscapes. [25]. the third one is the intersection of these viewpoints, implying that the environment, history, philosophy, and culture should be considered in the study of Geomorphosites. Using this method, protected areas acquire heritage and historical values [6, 7] Given its diverse geographical conditions, Akhlamad is one of the potential tourist areas with interesting landforms where unique and beautiful geomorphological landscapes have been formed due to geomorphic and climatic changes. In the present study, it was tried to study and evaluate geotourist characteristics and capabilities related to these landforms especially due to the existence of limestone and karst formations in this area while identifying the geomorphological forms of Akhlamad located in Chenaran County with potential for geotourism development near the pilgrimage and tourist city of Mashhad.

Therefore, Geotourism can have the most harmony with sustainable development and all economic, cultural, social and environmental dimensions. So, the necessary infrastructure should be provided for the development of geotourism and landscaping to achieve this goal. According to its climate and geological location, Iran has the most diverse landforms and new geological phenomena. The existence of these phenomena facilitates the conditions for the development of geotourism. In this regard, identifying and evaluating, introducing and creating geosites and geoparks can, in addition to preserving the geological heritage and preventing the destruction of environmental elements related to industrial societies, adding scientific content and professionalizing the tourism industry as well as the local economy and create effective employment. Iran's potential geoparks to historical monuments, cultural and biological phenomena and the coordination of this situation with the UNESCO index creates a suitable situation to provide the necessary infrastructure for the registration and list of the UNESCO World Heritage.

Considering the ever-increasing development of global geoparks and the competition to attract tourists through countries with geoparks, the officials of relevant organizations should provide the necessary infrastructure for the global registration of Iran's geotourism potentials in the list of UNESCO geoparks with more detailed planning. They should try to develop geotourism and attract foreign currency and

sustainable development. The identification and potential measurement of geosites such as Akhlamed Valley can be the basis for the creation of a new geopark with significant geodiversity in the eastern region of Iran.

1.1. Research Question

What are the main values and capabilities of Akhlamed Valley for tourism development?

The basic problem of Iran's tourism is the unknown variety and scattered potentials, especially its natural and geomorphological attractions. The review of scientific sources published inside and outside of Iran also confirms this issue. Therefore, this research tries to help tourism planners and policy makers by introducing the geomorphological capacities of a part of eastern Iran. And to introduce Iran's geotourism potentials to geoscientists, nature enthusiasts and natural environment protection all over the world. On the national horizons of Iran in which development targets for 2025 are defined, Iran intends to become one of the major tourist destinations in the world [40], and it can make more worthwhile the importance of this research.

1.2. Review of the Literature

Numerous studies have been performed over the past decade on landforms and Geomorphosites due to their important roles. Pereira *et al.*, (2007) evaluated the capabilities of tourism Geomorphosites in Portugal by selecting 154 potential Geomorphosites in Montesinho National Park leading to eventually 26 Geomorphosites with investment opportunities in the tourism sector. Serna and Gonzalez Trouba investigated the value of geomorphological sites in the Picos de Europa National Park. By classifying the sites into specific groups, they determined their value in each index. Comanescu *et al.*, (2011) evaluated the Geomorphosites of the Vista Valley. Reynard (2007) examined the concept of Geomorphosite and their attractions and proposed a new method for evaluating Geomorphosites.

In Iran, various researches have been conducted in different parts of the country. In a book entitled "Fundamentals of geotourism", Nekouie Sadry [31] examined the basic framework of this type of tourism and its scientific fields. Mokhtari [29] evaluated the ecotourism potential of Geomorphosites of the Asiyab Kharabeh basin in northwestern Iran using the Pralong method. Fotouhi et al., [10] investigated the geomorphotourism capabilities of landforms in the tourism region of Bistoon. Maghsoudi et al., [26] studied the Geomorphotourist capabilities of Mahabad city using the Comanescu method and found that the Saholan water cave is the best place for tourism development. Yazdi and Emami [43] studied the Geotourism Potentials of Iran. Pourfaraj et al., [37] investigated Conservation Management of Geotourism Attractions in Tourism Destinations. Hejazi, et al., [13] Evaluated Geotourism Capabilities of Geomorphosites of Osku County in East Azerbaijan Province Using Pereira and Pralong Method. Baboli Moakhar et al., [3] studied Capability Assessment of Geotourism Capabilities of Bahmai County Using Pereira & Reynard Models. Zahmatkesh et al., [44] studied Geomorphotourism and assessment of the potential of geomorphosites in Qeshm Geopark using the Pereira method. Mirkatoli et al., [28] investigated the Assessment of geological heritage in Cheshmeh Badab-Surt Geopark using the Pereira and Reynard methods (Erost village - Sari County). Arab Ameri [2] Compared evaluation of geomorpho-desert sites in Shahrood County towards sustainable tourism development, Geographical explorations of and Seyed Asadollah et al. [41] investigated the Geotourism potential evaluation of geomorpho-sites in Varkaneh village using the Periera method. Zanganeh Asadi et al., [46] studied A New Approach in the Evaluation of Geomorphosites and Geosites in Iran.

2. Methodology

To achieve the purpose of the research, a huge amount of data was used including documentary sources based on thematic mapping, descriptive and library studies, and field survey data to complete the research process. To collect data, a library study was performed by examining the documents related to the subject. Then, landforms were identified and located by conducting field trips. Having studied and identified the geomorphological characteristics of Geomorphosites using library studies and field surveys in the study area, the Geomorphotourist characteristics of the Akhlamad region were evaluated by the Pereira method. Accordingly, the capabilities of the studied Geomorphosites were assessed in several steps by field evaluations. In this method, the geomorphological value of a Geomorphosite is obtained by adding scientific and complementary indices and the managerial value is obtained by adding the protection and usage indices. The sum of these two main indices gives the final score of a Geomorphosite. Finally, the respective Geomorphosites were differentiated to evaluate the environmental and tourism potentials of the region.

2.1. Description of Study Area

The study area is located in the geological sheet 1: 100000 of Akhlamad [36]. The oldest exposed deposits in this area include rows of sandstone, shale, argillite, and dark gray to black charcoal clays of the Middle Jurassic age (Figure 1), which are named in the Akhlamad Geological Map as "Kashafrud Formation". In the study area, Kashfarud Formation is isoclinally underlain by the studied sequences. Following the dark shale and sandy rows of Kashfarud Formation, there are marl and shale sequences and gray to dark gray marl limestones of the Middle-Late Jurassic age, which are considered equivalent to Chaman Bid Formation. There is pale yellow to cream dolomitic limestone (equivalent to the Mozdoran Formation) of the Late Jurassic period in the form

of rocks in the whole area.

Mozdoran Formation is one of the geological formations of Iran located in Kopeh Dagh from Late Jurassic age. Lithologically, it consists of thick-layered limestone to the light-colored massif, porous dolomite limestone, and dolomite, which is about 500 meters thick in the pattern cutting but decreases rapidly to the southeast.

Mozdoran Formation is located on the Kashfarud (Shemshak) Formation with no obvious unconformity and is covered by red clastic sediments of the Shurijeh Formation. Available fossils show that this formation was formed during Late Jurassic (Figure 2).

The Mozdoran Formation is to some extent equivalent to Lar Lime in the Central Alborz and Esfandiar Lime in Tabas. Cretaceous deposits were not found in the study area. The major Cenozoic deposits include alternations of conglomerate, sandstone, marl, and limestone, among which there are basaltic andesite infiltrations of Paleogene in some places.

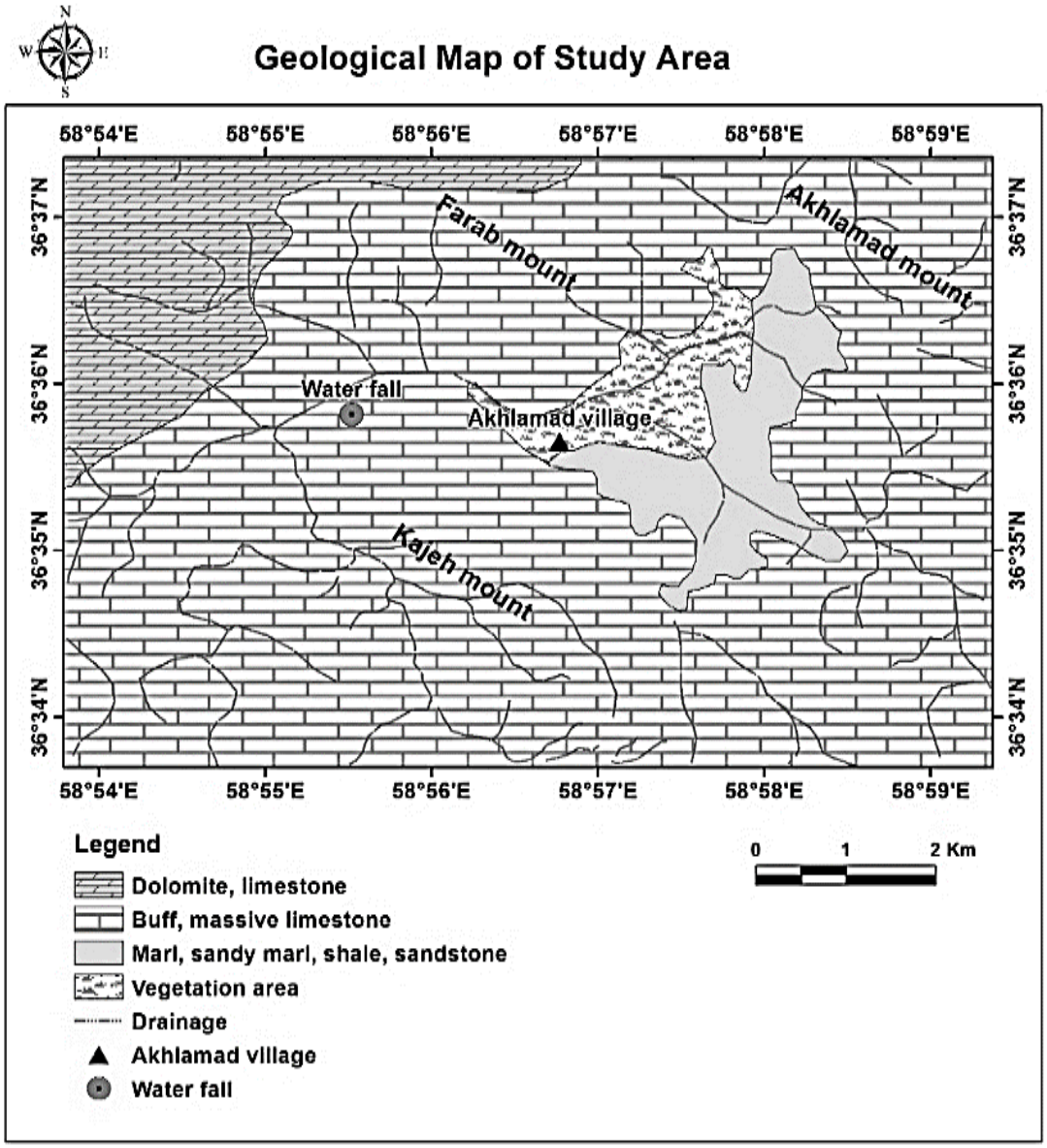

Figure 1. *Geographical location of the study area on the geological map 1: 100000. Source: Geological Survey of Iran, 2006.*

Due to the geological characteristics of Chenaran, there are more than 70 active mines with minerals of rubble, malone, marble, mountain mixture, gypsum, silica, limestone, and sand. All the mines are open-pit. Darband mine in Akhlamad located in the study area contains rubble minerals and was exploited in 2020 with an investment amount of 22,169,000,000 Rials. The mineral reserves in this mine are about 490,000 tons. Rubble stone in the entrance of Akhlmad Valley with a mineral reserve of 12,400 tons and an investment amount of 425,000,000 Rials was exploited in 2011 [23] There are also lead ore and mines in Akhlamad Mountains, which are not being exploited. Abandoned lead and zinc

mines of Akhlamad with geographical coordinates of 36 °38' 59 N and 36 °51' 59 E are located in the west of Chenaran in Khorasan Razavi province. The main lead and zinc mines of Central Alborz are in Upper Cretaceous carbonate rocks, while in Eastern Alborz, these and other deposits are in Jurassic carbonate rocks [4].

The study area has considerable karst landscapes that have emerged under the influence of internal and external morpho dynamic processes. Karst forms have resulted from the interaction of climatic phenomena and elements and geological conditions in calcareous zones. Such landscapes are one of the diversified environments with unique landscapes. They play a major role in the formation of landforms as Geomorphosites. Karst or dissolution processes are applied in some sedimentary rocks sensitive to dissolution such as limestone (carbonate) and evaporite rocks, leading to the creation of special roughness called karst [27]. About 11% of Iran's land area contains surface outcrops of carbonate and karst rocks and the aquifers in these rocks are the main groundwater resources [39]. In general, karst is a dynamic system combined of landscapes, organisms, energy, water, gas, soil, and bedrocks, the individual change of which impacts the whole system (Ibid: 18). Akhlamad drainage basin has two main geological characteristics playing an important role in karst erosion; thick karst calcareous formations and tectonic and structural factors [45].

The weathering and erosion processes of the third and fourth geological periods contributed to the construction of landforms in this area [5]. In the Pleistocene glacial periods, the main active shaping process on the other side of the 1900m level line of Akhlamad drainage basin was the erosion system next to the glacier (Mahmoudi, 1988). The temperature regime of the study area may fluctuate due to high altitude, latitude, and cold Siberian air masses in the winter and hot and dry winds in the summer. The average annual temperature plays an important role in the karstification process, especially in the erosion due to cold and humid weather. Annual rainfall and altitude are the main reasons for karst formation in the Akhlamad drainage basin [45].

Karst landscapes have economic, scientific, educational, recreational, and aesthetic values. Such areas as coastal landscapes are highly sensitive to various environmental hazards and must be managed protectively [24]. Today, these landscapes are considered a valuable natural collection due to their aesthetic, environmental, natural, and tourism aspects [45]. Therefore, karst areas, especially caves and valleys, have various scientific, human, and economic values [24]. Although there are diverse, attractive, and unique Geomorphosites in the karst areas of Khorasan, few systematic works have been performed on assessing the capability, management, protection, and sustainability aspects of Geomorphosites in the province. Therefore, the implementation of comprehensive evaluation models and methods in the development of scientific, cultural, and economic values based on the protection of heritage and geomorphic areas and the economic development of the indigenous community, is an essential process for establishing sustainable development. This leads to the establishment of balanced economic growth, the protection of natural heritage, the prevention of environmental degradation, the creation of job opportunities, and the improvement of the quality of the cultural landscapes [30].

2.2. Aesthetic Attractions of Akhlamad

Akhlamad is best known as the paradise of Khorasan due to its considerable beauty. The area is surrounded by white limestone walls. In spring, these walls are decorated with velvety green plants and while raining, several waterfalls are formed, creating a very interesting view. Akhlamad Gardens located on both sides of the river and on the slopes of the mountains have given special effect to this place. Numerous houses have been built on the river banks, hills, and slopes to the top of the mountains. Some of the houses are hidden among the trees and gardens. Akhlamad waterfall is characterized by vertical and tall walls of the Akhlamad Mountains, clean and pleasant air, different types of cherry and apple fruits. The Akhlamad River originating from a place called "Pish Bagh" and "Shir Morgh" has traveled a long distance through the bight of the valleys of "Manijeh Mountain" to flow into the Akhlamad Valley. The volume of water in this river is much higher in spring. The sewage of the river (from the gardens) in entrance of Akhlamad valley is used by newly constructed gardens for agricultural purposes.

2.3. Akhlamad Famous Springs

The famous and best-positioned springs are, respectively: 1. Deezbar spring; 2. Daraji spring; 3. Khahesh spring; 4. Sarborj spring; 5. Ghosl Khane spring; 6. Poonehzar spring; 7. Hatam spring; 8. Hesar spring; 9. Salimeh spring; 10. Donbeh spring; 12. Bolbol spring.

2.4. Akhlamad Mountain Range

It includes three mountains that are connected and surround Akhlamad. Indigenous peoples call it Mount Mizan, Mount Manijeh, and Mount Poru (which means full of water).

2.5. Akhlamad Waterfall

It is 40 meters high, located in the area of Akhlamad village with 36°N and 58°E. The calcareous nature of the Akhlamad Mountains has made deep circular cavities to be appeared under this waterfall

Figure 2. *Akhlamad waterfalls in winter and spring.*

2.6. Akhlamad Valley Walls

These walls are between 200 and 300 meters high. The most famous walls are White Wall, Allahu Akbar, and Eagle. These walls are popular choices for Iranian mountaineers, rock climbers, and ice climbers (Figure 3).

Figure 3. *Akhlamad Valley Walls.*

2.7. Akhlamad Historical Dam

It is located 3 km away from entrance of Akhlamad valley. This dam was built in the first half of the ninth century AH, upon the efforts made by Baisanghar Mirza Teymouri, the son of Shahrokh and the ruler of Toos (Figure 4).

Figure 4. *Akhlamad historical dam.*

2.8. Akhlamad Cave

This cave is located 2 km away from Akhlamad village (Akhlumad) in the northwest of Mashhad. The Akhlamad cave is 18 m long (Figure 5).

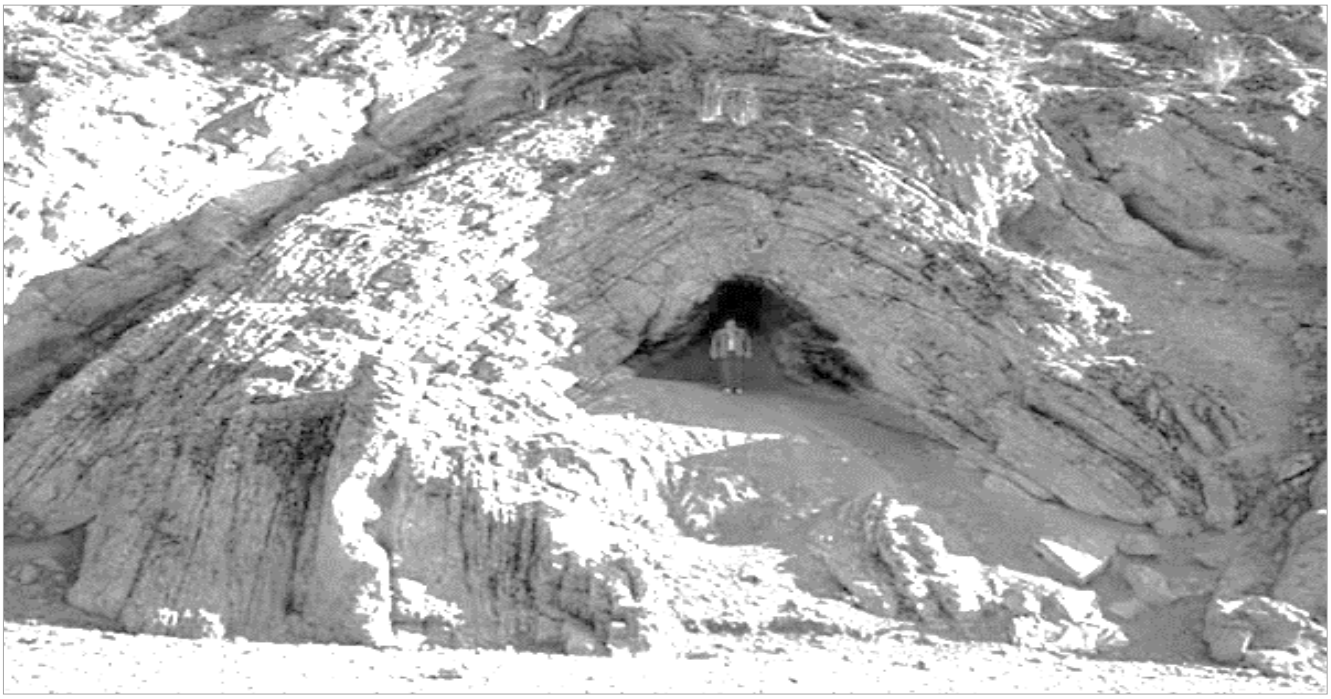

Figure 5. *Akhlamad Cave.*

2.9. Shah Abbas Throne

It is a beautiful vast area between the two 23-meter and 40-meter waterfalls in Akhlamad that owes its fame to its name. From this point, a 2 km-long river flows to the end of the valley and reaches Farab Mountain and Manijeh Mountain.

Many tourists visit the area each year, especially to take memorial photos.

2.10. Ajenneh Valley

It is a valley located in Akhlamad village. The altitude of the valley is 1440 meters above sea level and is located 17 km southwest of Chenaran county and 60 km away from Mashhad city. There is weather fluctuations in Akhlamad village and it is not so hot in summer or so cold in winter. Given the high altitude and heavy rainfall, the waterfalls of the valleys of Akhlamad have a large amount of water and captivating beauty in the first months of the year. Akhlamad main waterfall is 40 m high and the third and fourth waterfalls are located above it. Akhlamad waterfalls are located in the midst of Binalood Mountain and the continuation of Alborz Mountain range and is originated from Manijeh Mountain. Due to the calcareous nature of the Akhlamad valleys, deep circular cavities have been created under the waterfalls. Ammonite fossils in this region demonstrate that the sediments belong to the late Jurassic period. Ajenneh Valley is a very scary precipice and is located on the right side of the main waterfall of the village and indicates a distance of about one kilometer to the waterfall. Ajenneh is the plural of the word "jenn" (jinn) in Arabic, which means invisibility, stealth, and darkness. This valley is known as Ajenneh Valley because of its narrow and dark waterways. Ajenneh Valley is one of the sub-valleys of Akhlamad Valley (Figure 6).

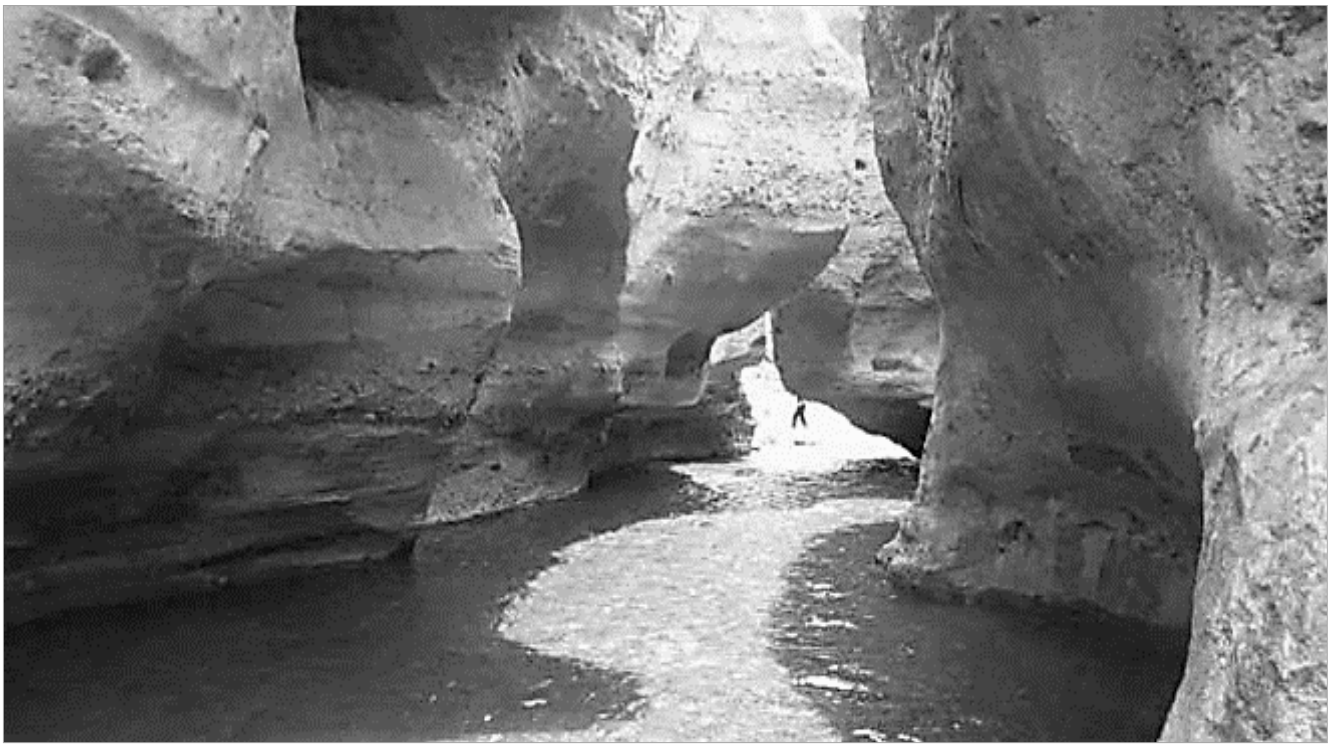

Figure 6. *Ajenneh Valley.*

2.11. Bidestan Waterfall

Dizbar spring located in the eastern Akhlamad has abundant water with a pleasant taste and is the main water source for most of Akhlamad gardens. The end of Dizbar valley is called "Bidestan" where a small waterfall is flowing (Figure 7). The whole area of gardens drinking from this spring is called "Dizbar" by indigenous people.

Its name was originally "Darbar" (meaning near a village) according to the encyclopedia of Iranian settlements (published in Tehran in 1960 AH) as archaeological studies indicate huge ruins of fortress and towers of an old castle. The water of "Dizbar" was so important that whenever a local family did not share in this water, no one married the children of this family [42].

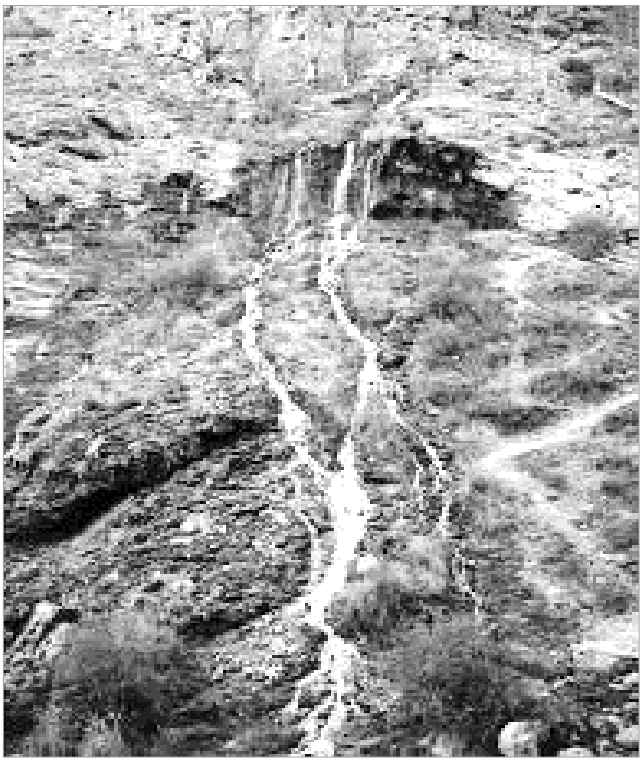

Figure 7. *Bidestan waterfall.*

3. Methodology for Evaluation of the Selected Geosites

The Pereira evaluation method was studied and the selected geosites of the study area were evaluated by the mentioned method.

3.1. Scientific Evaluation of Geomorphosites

A qualitative evaluation process is used to determine the true value, the use and requirement for protection. To determine the scientific value of a Geomorphosite, multiple indices are employed. The scientific index of a Geomorphosite is obtained by adding all sub-indices. In the Pereira model, some indices have higher scores than others. Scoring is done from zero to one and sometimes from zero to one half depending on the importance of the factors. In this index, scientific studies performed in the study area, the number of the respective phenomenon at the national level, their scarcity at the study area, intact Geomorphosite, the number of attractive geomorphological forms, the existence of other geological forms, and its value in geomorphology education are examined.

Table 1. *Scientific indices for evaluating the most suitable landforms for geotourism development (highest score 5.5).*

Intact geomorphological phenomenon	**Score**
Highest damage by human activities	0
Major forms damaged by natural factors	0.25
Damaged if the original forms are intact	0.50
Minor damage if major defects remain	0.75
No damage in forms	1
The number of attractive and diverse geomorphic forms	score
1	0
2	0.33
3	0.67
>3	1
The scarcity of landscapes at the national level	Score
More than five samples nationally	0
Between three and five samples nationally	0.17
Three samples nationally	0.33
Rare and unique nationally	0.50
Scientific studies in geomorphological journals	Score
Lack of related papers	0
Presentation in seminars and scientific and research papers (intermediate)	0.25

Intact geomorphological phenomenon	Score
Presentation of international papers and academic dissertations (high)	0.35
Rarity relative to the area	Score
Absence of the phenomenon among the first five samples	0
Absence of the phenomenon among the first three samples	0.25
As one of the three sample phenomena	0.50
As a very important phenomenon	0.75
A phenomenon with the exceptional occurrence	1
Educational value of geomorphic processes	Score
Limited visual value with no educational attractions	0
Limited visual value with limited educational attractions	0.38
Appropriate sample of processes and difficult description for non-experts	0.67
A good sample of processes and a good educational resource	1
Other geological forms with a valuable heritage	Score
No other geological forms	0
Existence of other forms unrelated to geomorphology	0.17
Existence of other forms related to geomorphology	0.33
Existence of other Geomorphosites with heritage value	0.50

Source: Pereira *et al.*, (2007) and research findings (field survey)

3.2. Evaluation of Geomorphosites by Complementary Index

In the evaluation of geomorphotourism, the existence of attraction is not enough and it is necessary to have additional attractions for the geomorphological attraction to be flourished. Cultural, historical, and ecological attractions can be considered complementary attractions to attract tourists. The list of cultural, ecological, and aesthetic evaluation indices of Geomorphosites is shown in Table 2.

Table 2. *Complementary indices of Geomorphosite evaluation (highest score 4.5).*

Cultural value	Score
No or damaged cultural forms	0
Cultural forms unrelated to landforms	0.25
Appropriate cultural forms unrelated to landforms	0.50
Insignificant cultural forms related to landforms	0.75
Material cultural forms related to landforms	1
Appropriate cultural forms related to landforms	1.25
Primitive landforms or high cultural relevance	1.50
Ecological value	Score
Unrelated to biological forms	0
Plant and animal attractions	0.38

Cultural value	Score
The best place to see plant and animal attractions	0.75
The importance of geomorphological forms for the ecosystem	1.12
The high importance of geomorphological forms for the ecosystem	1.50
Aesthetic value	Score
Thematic value: Landscape's visual uniqueness, landscape, landscape diversity, landforms color combinations, water and plant, no human destruction, proper access to observed forms	
Low	0-0.5
Middle	0.5-1
high	1-1.5

Source: Pereira *et al.*, (2007) and research findings (field survey)

3.3. Evaluation of Geomorphosites by Protection Index

In tourism literature, sustainability is a fundamental concept. The concept of sustainability was suggested by theorists and experts in the 1960's when mass tourism and its negative effects emerged in leading countries of tourism development. "Protection" in the Pereira model emphasizes the protection of natural resources and providing opportunities for future generations to use them.

Table 3. *Protection evaluation indices (highest score 3).*

Intactness	Score
Damaged by human activities	0
Damaged by natural processes	0.25
Damaged with the original geomorphological forms retained	0.50
Low damage with the original geomorphological forms retained	0.75
No damage and the original geomorphological forms retained	1
Vulnerability if using the site	Score
High vulnerability, with the possibility of loss and total destruction	0
Probable damage to geomorphological forms if used	0.50
Probable damage to non-geomorphological forms if used	1
Damage only to access networks (transportation)	1.5
Improbable vulnerability if used	2

Source: Pereira *et al.*, (2007) and research findings (field survey).

3.4. Usage Index

In the usage index, accessibility, visibility, and common and current use of Geomorphosites and support services of the site are examined. So, when the support services of a Geomorphosite are better and more accessible the investment value will be higher.

Table 4. *Usage evaluation indices (highest score 7).*

Access rate	**Score**
Difficult access and accessible only by a special tool	0
Access only by car and 500 meters on foot	0.21
Access by car and more than 500 meters on foot	0.43
Access by car and less than 500 meters on foot	0.64
Access by car and less than 100 meters on foot	0.86
Access by car and less than 50 meters on foot	1.07
Access by bus on the side road and less than 50 meters on foot	1.29
Access by bus on the main road and less than 50 meters on foot	1.50
Current use of geomorphological attractions	Score
Not upgraded and not used	0
Not upgraded and used	0.33
Upgraded as a site with landscapes	0.67
Upgraded as a geosite	1
Current use of other cultural and natural attractions	Score
No other attractions, Not upgraded, not used	0
Other attractions, Not upgraded, not used	0.33
Other attractions, upgraded, not used	0.67
Other attractions, upgraded, used	1
Visibility	Score
Very poor visibility or invisible in all areas	0
Only visible by special tools (artificial light)	0.30
Limited visibility due to short and small trees and plants	0.60
Good visibility but requires little movement	.090
Good visibility for all geomorphological forms	1.20
High visibility for all geomorphological forms.	1.50
Equipment and support service	Score
24-hour support service and > 25 km away from the attraction	0
24-hour support service and 5-10 km away from the attraction	0.50
24 hours a day with support service and < 5 km away from the attraction	0.75
24-hour support service and < 5 km away from the attraction	1
Protection rules and usage restrictions	Score
Full protection and no use	0
Protection and limited use	0.33
No protection and unlimited use	0.67
Protection and unlimited use or very few limitations on use	1

Source: Pereira *et al.*, (2007) and research findings (field survey).

4. Discussion

Enjoying the geomorphological landscapes of valley areas and karst landscapes in these valleys requires identifying their geomorphological characteristics and attractiveness. These Geomorphosites formed in valley areas experience unique features and phenomena due to morphological diversity and therefore can be introduced as good attractions for educational tours and scientific-research tourism for researchers, adventurous tourists, and explorers. They are also considered as recreational and sports attractions. The Geomorphosites evaluated in the present paper using the authors' field observations are the river, tall limestone walls, karst valleys (Ajenneh valley), calcareous sinkholes (dolins), and Akhlamad main waterfall and cave. Figure 5 shows some of these Geomorphosites.

Figure 8. *Calcareous holes (dolines).*

The basic concepts of the identified landscapes are described in the table below. In the table, the structure of these forms arising from erosive processes and morphological features in the valley and mountainous areas is briefly reviewed.

Table 5. *The most important geomorphic landscapes in the study area.*

Features	Natural properties
River	The river is referred to as the bed and the path of a stream. Rivers primarily form alluvial fans at the foot of the mountains, and then contribute to the development of the plains by accumulating alluviums along the route.
Rock walls	Walls are rocks higher than 50 meters, which are more than one rope length with a slope of more than 75 °. They have different types of rocks, slopes, and hardness, which is also called "steep". The walls are elevated, natural, and impassable sidewalks with steep cliffs and are considered a part of the mountain.
Karst valleys	A valley is a long depression between two hills that extends in one direction. Karst valleys are U-shaped narrow deep or V-shaped dry asymmetric or a combination of the two. River valleys formed by river movements are usually v-shaped. Their shape depends on the flow characteristics.
Calcareous holes (dolins)	These forms are among the most significant morphological karst phenomena in the Akhlamad drainage basin. The dolins observed are of dissolution type and are formed by the dissolution of limestone rocks. Scattered dolins and relatively deep holes in the basin surface indicate geomorphic maturation of karst.
Waterfall	A waterfall is a geological phenomenon in which the water of a river flows from a plateau or high place at high velocity into a plunge pool below. A waterfall is an abrupt drop of water, usually caused by a rocky ledge in a river that is either horizontal or gently sloping toward the top of the river and settles on softer rocks. The softer rocks below are eroded quicker than the harder rocks so that the harder rocks may hang and eventually a waterfall forms.
Jama and calcareous caves	Jama is a vertical or near-vertical karst channel that open to the ground. The area of the caves in the Akhlamad drainage basin is not very large and there are few helictite shapes and calcite dripping stones. Most of these caves are almost dry. The largest cave in the basin is Akhlamad Cave with a length of 17.5 meters near the first waterfall of Akhlamad.

Source: Zanganeh Asadi *et al.*, 2002 and research findings

To understand the relationship between the cultural landscapes and Geomorphosites of the region, Figure 2 shows the main way to access Akhlamad and the study area relative to Mashhad. Akhlamad is located in Khorasan Razavi province in northeastern Iran and in Chenaran County. It is located 84 km northwest of Mashhad (Mashhad-Quchan Road) and in the heart of Binalood Mountains. The famous waterfalls of Akhlamad are located 2 to 3 km away from the village and to reach them you have to pass through the middle of the village. Akhlamad is about 17 km away from Chenaran County. Since natural and cultural attractions have made Akhlamad one of the most important tourist destinations for foreign and domestic tourists in Mashhad, it is necessary the roads are of proper access so that the area is identified and exploited by tourists.

5. Conclusions

The results of field studies and evaluation performed by the method studied in Akhlamad are as follow:

As can be seen in Table 2, by evaluating the scientific index of the selected Geomorphosites, it was found that the highest scores belong to the dolins and rock walls, respectively. Walls, as one of the most important and unique phenomena, suffered minor damage due to erosion and weathering, and their main forms have remained. Other Geomorphosites with valuable geological heritage along with them add to the importance of this feature and are a very good example of karst erosion processes and karstic calcareous formations and can be used as an important educational resource by researchers, students, and science and adventure tourists. These walls have geomorphic shapes such as avens, seams, cracks, and faults and are among the unique phenomena at the national level. Dolins or karst sinkholes are scientifically rare phenomena in the study area, and given the geographical and climatic characteristics of the region are a very good example of the complete karstization process of calcareous formations and along with other existing natural heritage, they have created a variety of landscapes and scientific attractiveness.

Table 6. *Final evaluation of Akhlamad Geomorphosites by Pereira method.*

	Akhlamad valley Geomorphosites	Geomorphological values		Managerial values		Total scores in the Pereira model
		Highest scientific index 5.5	Highest complementary index 4.5	Highest usage index 7	Highest protection index 3	
1	River	1.88	1.88	4.97	0.5	9.23
2	Rock walls	4.75	3.87	5.17	1.25	15.04
3	Ajenneh karst valley	3.75	3.38	4.67	1.25	13.05
4	Karst sinkholes (dolins)	4.67	2.63	3.77	1.5	12.57
5	Akhlamad main waterfall	3.55	3.57	5.6	0.75	13.47
6	Calcareous cave	2.55	2.7	1.83	0.75	7.83

By evaluating the complementary index of the selected Geomorphosites, it was found that rock walls had the highest score (3.87) followed by Akhlamad main waterfall (3.57). Cultural (stories and legends) and historical and ecological (plant and animal diversity) attractions were considered complementary attractions to attract tourists.

By evaluating the protection index of the selected Geomorphosites, dolins obtained the highest score (1.5) followed by rock walls and karst valleys (Ajenneh Valley as the selected geosite) (1.25), respectively. The most important variable studied in this index is the intact status while using the site. Field studies showed that due to the escalating interest of adventurous tourists in karst sinkholes that are very attractive and the lack of planning for natural heritage protection in this area regarding the restriction and management of access to geosites given their environmental tolerance capacity, protection index in this area was obtained less than 50%. The "protection" characteristic in the Pereira model emphasizes the sustainability and protection of natural resources to ensure their transmission to future generations.

By evaluating the usage index of the selected Geomorphosites, the highest score belongs to rock walls (5.17) followed by Akhlamad River (4.97), respectively. In this index, accessibility, visibility, common and public use of Geomorphosite, and support services of the site are examined. Accordingly, Geomorphosites of rock walls and rivers have better support services, are more accessible, and have a higher investment value. The presence of sidewalks near the river to access the first (main) waterfall of Akhlamad, amenities and accommodation for tourists, and the impressive view of the high

cliffs indicate significant potential for tourism development planning at this site. However, it should be noted that weak management in using the site has caused irreversible physical and cultural damage to this area. So practical suggestions for optimal management and exploitation of Akhlamad natural heritage are presented as follows:

1. Studying and identifying the geo sites of Akhlamad drainage basin to develop geotourism in the peripheral areas of Mashhad and diversifying tourist attractions and increasing the number of tourists and their length of stay in Mashhad metropolis.
2. Physical pathology of phenomena and geomorphic features of the area due to unprincipled exploitation in recent decades.
3. Preparing a feasibility plan for tourism land development in the study area.
4. Defining investment opportunity packages for geotourism, adventure tourism, rural tourism, health tourism, and sports tourism.
5. Establishing or using the potentials of existing non-governmental organizations (NGOs) for educating environmental considerations of use and tourism in natural sites and protection of the natural heritage of Akhlamad.

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Abbreviations

ACECR	Academic Centre of Education, Culture and Research
GIS	Geographical Information System
STEM	Technology, Engineering and Mathematics
UNESCO	United Nations Educational, Scientific and Cultural Organization

Conflicts of Interest

The authors declare no conflicts of interest.

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