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The Role of Damavand Mountain as Geological Heritage in line of Sustainable Development

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Abstract
In this research, the Damavand Mountain as a unique geological phenomenon in Amol County, Mazandaran Province with special view on its role in sustainable tourism development was studied. The methodological process was based on: the inventory and preliminary selection of geosite, a semi-quantitative geosite assessment and the application of the strengths, weaknesses, opportunities, and threats (SWOT) matrix to establish geotourism development strategies within a framework of sustainability. On the based on studied done ,the Damavand mountain is a real geosite with high geo-touristic potential which include : water fall , hot spring , glacier ,volcanic crater which are a geological heritage with outstanding scientific, cultural , touristic ,industrial ,and educational values. According to the results of the IELIG method in this study, the geosite of Damavand has 'very high' interest values taking into account their scientific, academic and tourist interests and has necessary conditions for geotourism development. The SWOT analysis reveals that travel itineraries that combine cultural heritage elements and geosites could offer a real alternative for the region's sustainable development through geotourism.

Keywords: Damavand, Geological Heritage, Mountain, Sustainable Development.
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1. Introduction

Sustainable development is an organizing principle that aims to meet human development goals while also enabling natural systems to provide necessary natural resources and ecosystem services to humans (Johnson, 2023). The desired result is a society where living conditions and resources meet human needs without undermining the planetary integrity and stability of the natural system(Mensah, 2019) Sustainable development tries to find a balance between economic development, environmental protection, and social well-being. The Brundtland Report in 1987 defined sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. The concept of sustainable development nowadays has a focus on economic development, social development and environmental protection for future generations. Geosites are one of the important factors in sustainable development.Geo-sites are geological or geomorphological sites with a recognized value through an audit, assessment , and selection process, that conservation of them for scientific, educational, geo-tourism ,and other uses is an essential part of the conservation of geoheritage. Geo-sites in urbanized areas rarely introduce as forms of abiotic nature conservation(Reynard and Brilha, 2018).Still few exist in town centers, with most Geo-sites found on the outskirts of cities, where there are more open spaces. Even so, urban public spaces contribute to the visibility and protection of the city's geodiversity in the form of Geo-sites (Zwoliński et al., 2018). some of these Geo-sites can have national or international importance. it is exciting to know ,the economic exploitation of unique geoheritage features is the basis of geo-tourism In general, geo-tourism is a type of sustainable tourism that promotes the protection of natural areas at local and international levels . In Newsome and Dowling's words, Geo-tourism 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 to the emphasis on understanding the underlying and shaping processes of these complications (Newsome and Dowling, 2018) . the geotourism sector dynamics are prone to be influenced by impacts and crises deriving from environmental, climatic, and social factors (Ponce, et al., 2018).

2. Literature review

The term geodiversity was first introduced in the early nineties. According to Gray et al. (2013) geodiversity is the variability of Earth's surface materials, landforms, and physical processes (abiotic elements). The Materials of geology are the rocks, soil, or the water; mountains, glaciers, and lakes are examples of landforms; and soil formation, coastal erosion, and sediment transport could be mentioned as processes. A definition of geodiversity, at a local scale, was suggested as a synthesis of the landscape that includes geological, hydrogeological, geomorphological, and climatic elements and processes (Brilha, 2016). The Law of Natural Heritage and Biodiversity , defines it as “The variety of geological elements, including rocks, minerals, fossils, soils, landforms, formations and geological units and landscapes that are the product and record of the evolution of the Earth”. Geodiversity must be regarded as part of the natural heritage of the territory,which shapes the evolution of the planet and favors the development of life (Urresty, et al., 2015;Carrión, et al., 2018).When the constituent elements of geodiversity have a high scientific value, they are known as geological heritage or geoheritage (Carcavilla Urquí, et al., 2007)

Geoheritage is inherent to natural heritage. It includes forms, elements, and structures originated by geological process and has a crucial role in understanding Earth’s history (Erikstad, 2013) (Herrera-Franco, et al., 2021).Social perception of geodiversity and geological heritage has changed over time. Today, it is considered a right, a need, and a duty to protect the environment through the safeguard of geosites (Prosser, et al., 2018).Movable geological heritage also exists; it refers to vulnerable elements of earth sciences exposed to natural degradation or human action that can—or must—be protected ex situ. Their inclusion into a museum collection often means the only chance for the preservation of these invaluable inanimate natural monuments (Jakubowski,2004; Reis, et al., 2014).The existing procedures are improving and evolving to provide a global evaluation of the geological heritage, considering tourist, scientific, and academic criteria. The geological routes (georoutes) are itineraries that aim to the geological heritage’s value through the connection of different geosites. In this article, The Role of Damavand Mountain as Geological Heritage in line of the development of sustainable tourism by applying the semi-quantitative method of the IELIG and an analysis of strengths, weaknesses, opportunities, and threats (SWOT)within the framework of geo-tourism is discussed.

3. Research methods

In this research, the IELIG method was applied to identify and select sites of geological interest (SGI) or geosites. Also is use a SWOT analysis to evaluate the relationship between the geosites and the community. The IELIG does not only identify geosite targets of the inventory and their geological environment, but it also provides a diagnosis to design geoconservation measures. The study was structured into three stages .first phase consisted of compilation of information, inventory, and preliminary selection of potential geosites; in second phase, the IELIG method was applied for the assessment of the selected geosites; and finally, third phase involved SWOT analysis of the geosites regarding their contribution to the geotourism development of the region. The IELIG method is the base methodology recommended by the ASGMI (Ibero–American Association of Geological and Mining Surveys) for assessing sites of geological interest

(Chylińska, 2019).In general terms, this method define the instrumental values of geosites (scientific, educational, and recreational tourism potential), together with susceptibility to degradation and protection priorities. (García-Cortés, et al., 2013).

4. Result

4.1.Geographical setting of Damavand mountain

The Damavand mountain place in 35°57′04″N 52°06′32″E in the middle of the Alborz range, adjacent to Vararu, Sesang, Gol-e Zard, and Mianrud. It is near the southern coast of the Caspian Sea, in Amol County, Mazandaran Province, 66 km (41 mi) northeast of the city of Tehran (fig 1) .the Mount Damavand is a dormant strato-volcano and is the highest peak in Iran and western asia, the highest volcano in asia, and the 3rd highest volcano in the eastern hemisphere (after Mount Kilimanjaro and Mount Elbrus), at an elevation of 5,609 metres .

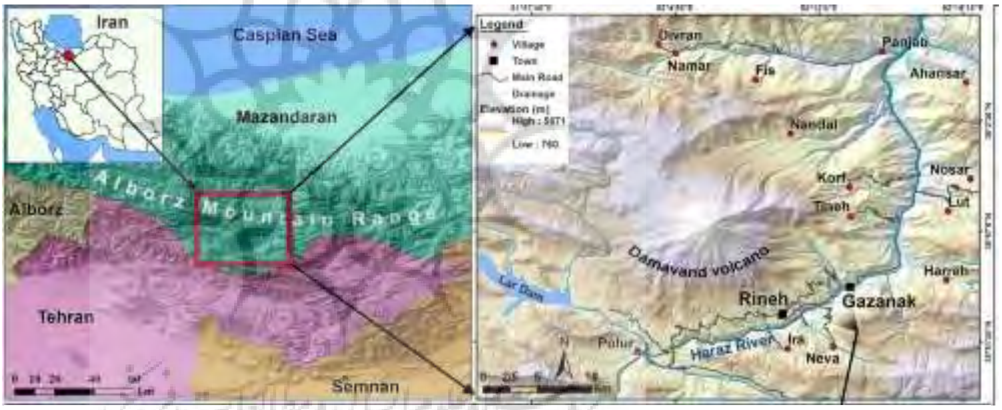

Fig 1. Situation of Damavand Mountain in Alborz Mountain Range

4.2.Geological setting and structure of Damavand mountain

Mount Damavand rises within the Alborz range in northern Iran, separating the Iranian plateau to the south from the Caspian Sea in the north. This range rises as a result of the collision between the Arabian and Eurasian tectonic plates. This collision is similar to the collision between the Indian and Eurasian plates to the east, which is causing the Himalaya to rise and does not usually create volcanic activity. Despite this, recent research suggests that a hot region created by the collision is what caused the volcano to rise. Seismic wave patterns from earthquakes around the volcano indicate that a magma chamber is present between

2 and 5 kilometers (1.2 and 3.1 mi) below the surface. This is separated into two areas - an inner region of hot, likely molten, magma between 3 and 4.5 kilometers (1.9 and 2.8 mi) depth that is surrounded by an area of dense cooled magma. The top of the chamber is believed to lie to the south of the summit, trending somewhat to the west with depth. Most volcanic activity originates from the summit area. A few flank vents have been noted, but these are largely on the upper slopes to the southwest and northeast of the summit. A secondary crater, termed Haji Dela, has some young lava flows 4 kilometers (2.5 mi) northeast of the summit. volcanic activity in the Mount Damavand region first occurred in the Pleistocene almost 1.78 million years ago, but the current edifice began to be built around 600,000 years ago. Its last eruption was around 5300 BCE in the Holocene. Its steep cone is formed of ash and lava flows mainly of trachyte, andesite, and basalt. Most eruptive activity appears to be lava flows, though some small pyroclastic flow deposits have been noted in drainages radiating from the mountain. One major explosive event is known to have erupted about 280,000 years ago. Quaternary lavas are directly on the Jurassic sediments. The volcano is crowned by a small crater with sulfuric deposits. Despite the lack of historical eruptions, ongoing thermal activity at Mount Damavand suggests the volcano is not extinct. Mineral hot springs are mainly located on the volcano's flanks and at the base, giving evidence of volcanic heat comparatively near the surface of the earth. Hot springs at the base and on the flanks and fumaroles near the summit indicate a hot or cooling magma body still present beneath the volcano. The area around the volcano is the most thermally active in Iran and the springs are being monitored to see if fluctuations in water volume and mineral content are useful in crude prediction of large regional earthquakes. A few glaciers are present on the upper slopes of Damavand, the largest of which is Yakhar Glacier. During the Last Glacial Maximum, the area covered by glaciation was much larger and the climatic snow line was between 600 and 1,100 meters below what is seen in the present day.

Fig 2. Images of Mount Damavand with related phenomena

4.3 Assessment(IELIG) and Analysis (SWOT) 0f Damavand Mountain.

The IELIG method was applied for the semi-quantitative Damavand Geosite assessment. This procedure, unlike others, considers protection priority (Pp), which is an essential indicator of priorities in conservation actions. Table 1 shows the parameters and weights established by the IELIG to assess the scientific (Sc), academic (Ac) and touristic (To). value of each site. A score of 0 to 4 is assigned to each parameter. interests based on [19]. Interest value rank (0, 1, 2, 3, or 4). Weight (constant values in %). Interpretation: maximum (400), very high (267–400), high (134–266), medium (50–134), low (<50).

Table1. Established parameters to assess scientific (Sc.), academic (Ac.), and touristic (To)

Parameters	Value	Interest of the Geosites		
		Scientific (Sc.)	Academic (Ac.)	Touristic (To.)
Representativeness	0 to 4	20	5	0
Standard or reference site		5	5	0
Knowledge of the site		10	10	0
State of conservation		5	5	0
Conditions of observation		5	5	5
Scarcity, rarity		0	5	0
Geological diversity		20	20	10
Educational values		15	20	10
Logistics infrastructure		5	5	5
Population density		0	0	5
accessibility		0	5	5
Size of site			0	10
Association with other natural elements			5	5
Beauty		5	5	10
Informative value		10	5	15
Possibility of recreational and leisure activities				5
Proximity to other places of interest				5
Socio-economic environment				10
Total (weight)		100	100	100
Total		Sc./ Ac./ To.= value × weight		

The values obtained for geosite (i.e., scientific, academic, and tourist interest) considered in the study area (Table 1), the aim is to analyze to what extent its protection is a priority. Equation (DS = Fr.*vul /400)) is used to calculate the degradation susceptibility (DS), based on parameters, such as fragility and vulnerability due to anthropic threats and assigned weights (García-Cortés, et al., 2013), shown in Table 2.Interpretation of DS: maximum (400), very high (400–200), high (199–68), medium (67–13), low (<13).

Table 2. Parameters of degradation susceptibility (DS) and weighs of each parameter**.**

Parameter	Fragility (Fr.)	
	Value	Weight
Geosite size	0 to 4	40
Vulnerability to looting		20
Natural hazards		40
Total (weight)	Fr. = value × weight	
Parameter	Vulnerability (Vul.)	
	Value	Weight

Proximity to infrastructures		30
Mining exploitation interest		5
Protected area designation		15
Indirect protection		10
Accessibility	0 to 4	15
Ownership status		5
Population density		10
Proximity to recreational areas		10
Total (weight)		100
Total (Vul.)	Vul. = value × weight	

From the degradation susceptibility (DS), Equations 1–3 were used to obtain the values of protection priority (Pp) in its different domains: scientific Pp (Sc.), academic Pp (Ac.), and tourist or recreational Pp (To.)The global protection priority Pp (Equation 4 generates a comprehensive value about the state of the geosite;it can be used to update the inventory of geosites, and to focus on those places that need restoration or application of appropriate conservation measures.

Table 3. Assessment geosite in terms of scientific (Sc.), academic (Ac.), touristic (To.), and average (Av.) interest, susceptibility to degradation (DS), vulnerability due to anthropic threats (Vul.), and scientific (Pp (Sc.), academic (Pp (Ac.)),touristic (Pp (To.), and global (Pp) protection priority.

Sc.	Ac.	To.	Av.	DS	Pp (Sc.)	Pp (Ac.)	Pp (To.)	Pp
380	370	370	373.33	15.75	14.21	13.48	13.48	13.72

1

$$\mathbf{Pp\ (Sc.)} = (\mathrm{ISc.})^2 \times \mathrm{DS} \times (1/400^2)$$

$$\mathbf{Pp\ (Ac.)} = (\mathrm{IAc.})^2 \times \mathrm{DS} \times (1/400^2)$$

2

$$\mathbf{Pp\ (To.)} = (\mathrm{ITo.})^2 \times \mathrm{DS} \times (1/400^2)$$

$$\mathbf{Pp} = \left(\frac{\mathrm{ISc.}+\mathrm{IAc.}+\mathrm{ITo.}}{3}\right)^2 \times \mathrm{DS} \times (1/400^2)$$

Table 4. SWOT analysis of the study area. The matrix combines internal features (i.e., strengths and weaknesses) identified by the letters (S) and (W) and external features (i.e., opportunities and threats) identified by letters (O) to (T)

Strengths	Strategies
S1. Variety of attractions, such as water-falls, rock formations, paleontological	S1.O 2. Develop plans focused on promoting attractions through geological routes for tourists.

Opportun	Strategie
O 1. Boost the economy of the province.	S1.T 2. Promote the development of conservation and protection plans for geosites with the community's support to prevent

Weaknes	Strategies:
W1. Limited promotion and brochures about geosites and geotourism. W2. Lack of knowledge and disinterest of the population.	W2. T 3. Involve experts in preservation and conservation issues to develop initiatives that prevent deterioration and improve the quality of

Strategies:	Threats
W1.O1. Generate geotourism promotion projects that serve as an alternative to improve the population's economic conditions and seek to promote integrated tourism.	T 1 . Lack of private economic resources that facilitate the implementation of

4.4. Importance of Damavand Mountain in sustainable tourism development

Damavand mountain is a geomorphological phenomenon that attract many tourists through the beautiful and unique scenes they exhibit. The outflow of yellow sulfur gas with steam is pretty excellent. Also the mountain , has a important hot spring as name Larijan hot spring in a village by the name of Larijan in the district of Larijan in lar valley. The water from this spring is believed to be useful in the treatment of chronic wounds and skin diseases and is bottled for distribution throughout Iran. Near these springs there are public baths with small pools for public use. A few glaciers are present on the upper slopes of Damavand, the largest of which is Yakhar Glacier. During the Last Glacial Maximum, the area covered by glaciation was much larger and the climatic snow line was between 600 and 1,100 meters below what is seen in the present day.Mount Damavand is important as a volcanic mountain with a history of lava flow and formation of Baltic rocks in the region. also There is a frozen waterfall-icefall about 12 m (39 ft) tall. The Wildlife in the mountain is very interesting and many tourists meet them every year.

5. Discussion and Conclusion

The IELIG method makes it possible to consider environmental-territorial characteristics in the assessment. According to the results of the IELIG method applied in this study, the geosite of Damavand has 'very high' interest values taking into account their scientific, academic and tourist interests. The DS values demonstrate that geosite that are located close to infrastructures, such as main roads, or that lack any indirect protection, have high vulnerability values due to anthropic threats and require immediate intervention. on the base of this, the susceptibility to degradation was evaluated and classified into 'high', 'medium' and 'low' categories which the studied geosite fall into the 'high' category. this site is vulnerable due to their easy access and lack of indirect protection. so has a 'high' protection priority level, which indicates the need for urgent or short-term protection measures. Study of the mountain was evaluated by the IELIG method (García-Cortés, et al., 2013)which proved that it can provide a basis for the development of geotourism in the area and can promote social development of territory with outstanding geological heritage (Franco, et al., 2020). In general, the existing volcanic geoheritage includes elements that are significant tourist attractions (Erfurt-Cooper, 2011). The diversity of these elements in the area offers the opportunity to promote volcanology related geo-education, awareness of geological hazards, as well as understanding the resilience of communities that have experienced the effects of volcanic activity. Regarding educational values, the geosite score between 2 and 4 points, which suggests that teaching materials are already in use or that the site has a potential at some level of the educational system (schools, colleges, universities).Additionally, this geosite has good access roads and are associated with natural and cultural heritage elements. so, the mount

Damavand , meet the necessary conditions for geotourism development, such as accessibility and connectivity, other associated recreational activities, tourism facilities and services, and state of conservation.
From the methodological point of view, semi-quantitative evaluation of geosite (Brilha, 2016) is a useful approach to establish the bases of future geotourism perspectives in a given territory. One of its advantages is the identification of weak points in the analyzed interests, warranting objectivity in the study. For the obtained results to be more accurate, it is recommended to use a combination of several methods/methodologies(Ruban,2010).The geosite of Damavand with having interesting geomorphological phenomena assessment and analysis (Swot) reached the 'very high' scores in terms of scientific (Sc.),academic interest (Ac).,and tourist interest (To.) interests and as well ,presents erosional unconformities and interlayered glacial deposits , can be an object of study by the local and international geoscientific community, mostly due to its ease of access. This condition also makes it exposed to anthropic activities, which increases its vulnerability. The based on studied done ,more significance of this mountain as a real geosite, is increased by the facts that it is the highest mountain in in Asia, and the 3rd highest volcano in the eastern hemisphere and hosts a large wildlife reserve. The aim , in SWOT analysis(the strengths, weaknesses, opportunities, and threats) (Dyson, 2004) was to determine the area's potential in a more ambitious future project and to propose initiatives for the efficient and effective use of the geosite and its environment. The SWOT analysis shows that one of the greatest strengths of the selected geosite is their outstanding geomorphologically phenomena value through which they could offer excellent opportunities to foster geotourism and to boost the economy. In general, the geotourism proposed here represents a sustainable enterprise that is compatible with the socio-economic activities of the area. Furthermore, these actions can contribute to the improvement of the quality of life of local people. The SWOT analysis contribute to the development of proposals, such as geotourism promotion projects and travel itineraries (Franco, et al., 2020).It also highlight the need for provincial, and parochial authorities to collaborate with academics and businesses to advance the sustainable development of geosites.

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