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ORIGINAL ARTICLE

# Assessment of Urban Geomorphological Heritage for Urban Geotourism Development in Khorramabad City, Iran

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## Abstract

Inventory and assessment of urban geomorphological heritage as a fundamental necessity and prerequisite for urban geotourism development are the main purposes of this research. Accordingly, the present study has been carried out in Khorramabad City, Iran. This research has been conducted using inventory and quantitative assessment of urban geomorphological heritage through fieldwork and (Brilha Geoheritage 8 (2):119–134, 2016) method with modification for urban geomorphosites. The results showed that among the 32 geomorphosites inventoried in karstic, fluvial, tectonic, anthropogenic and specific geomorphosites categories, the Falak-ol-Aflak Castle Hill has the highest score in all three scientific, educational and geotourism criteria. The highest degradation risk due to urban development is in the Absharan Valley. The lowest scientific, educational and geotourism value is related to the Masur Hill, Robat River and Gilvaran Cave respectively and the lowest degradation risk is related to the Gilvaran Cave. The total value of the geomorphosites varies between scores of 28 and 94 in all criteria. In general, in all three criteria, most urban geomorphosites are of high value, indicating the high potential of Khorramabad City for urban geotourism development. Further, due to intensive human activities in the city proper and its extraterritorial jurisdiction, they often require special protection; hence, paying attention to the conservation status of these geomorphosites is essential for preserving their scientific, educational and geotourism values.

**Keywords** Urban geoheritage · Urban geomorphological heritage · Urban geomorphosite · Assessment · Urban geotourism · Khorramabad City

## Introduction

In recent years, the ideas of urban geological heritage, urban geomorphological heritage and urban geotourism have attracted the attention of scientists and experts alike (Borghi et al. 2014; Del Lama et al. 2015; Chan and Godsey 2016; Pica et al. 2016, 2017; Reynard et al. 2017; Habibi et al. 2018; Erikstad et al. 2018; Chylińska and Kołodziejczyk 2018; Melelli 2019). Cities, in addition to man-made landscapes, often have unique geological and geomorphological phenomena, with many urban areas of the world preserving very interesting instances of geoheritage (Rodrigues et al. 2011; Liccardo et al. 2012; Reynard et al. 2017). An urban geomorphological heritage has both a natural and anthropogenic genesis (Del Monte et al. 2013; Reynard et al. 2017) that can be introduced, protected and managed for urban geotourism development. Cities are often tourist destinations and have the genetic potential for their geomorphological heritage (Reynard et al. 2017). Specific sites that contribute to understanding the interactions between geomorphology and urban development and represent geomorphological processes in an urban area can also be introduced as part of the urban geomorphological heritage (Reynard et al. 2017). Therefore, urban geomorphological heritage can be defined as a landform (natural and anthropogenic) and specific sites with scientific, educational or geotourism/recreational value within a city proper and extraterritorial jurisdiction (ETJ). In addition to the city proper, the geomorphological heritage can also be considered urban geomorphological heritage in the extraterritorial jurisdiction of a city, because the city's extraterritorial jurisdiction is under the control of the municipal corporation or agency that constitutes the city government and will become city proper in the future due to urban growth. It is, therefore, necessary that urban geomorphological heritage is

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also protected in the city's extraterritorial jurisdiction that is not damaged in the urban development process.

According to previous studies (Reynard 2008; Rodrigues et al. 2011; Hose 2012; Del Lama et al. 2015; Brilha 2016; Górska-Zabielskamaria and Zabielski 2017; Reynard et al. 2017; Reynard and Brilha 2018), urban geotourism is the scientific, touristic and educational use of natural and anthropogenic geosites and geomorphosites (urban geoheritage) within a city proper and its immediate surrounding territories. Conservation of urban geosites and geomorphosites is very important through promoting public awareness, understanding, learning and research for current and future generations. The components of urban geotourism, on the one hand, consist of all geosites and geomorphosites in cities with natural or anthropogenic genesis that have scientific, educational, tourist values and worthy of conservation (such as geological formations, geoarchaeological sites, caves, springs, erosional forms, cluse, local stones used in the facade of monuments, bridges, historical buildings, and sculptures) and, on the other hand, the tourism industry in cities.

In recent years, several studies have been conducted to introduce the tourism potentials of urban geological and geomorphological heritage (Del Monte et al. 2013; Del Lama et al. 2015; Palacio-Prieto 2015; Kubalíková et al. 2017; Ticar et al. 2017; Pica et al. 2016, 2017; Reynard et al. 2017; Portal and Kerguillec 2018; Avelar et al. 2018; Da Silva 2019), but the studies are at an early stage and require further reflection by the scientific community. Although there have been many studies to date on the assessment of geomorphological heritage in natural and rural areas (Serrano and Gonzalez-Trueba 2005; Pereira et al. 2007; Zouros 2007; Erhartic 2010; Coratza et al. 2011; Farsani et al. 2011; Feuillet and Sourp 2011; Fassoulas et al. 2012; Bollati et al. 2013; Sellier 2016; Reynard et al. 2016; Clivaz and Reynard 2018; Maghsoudi et al. 2019), in particular, however, the development of geomorphological heritage evaluation methods in urban areas, for example, Pica et al. (2017), has received less attention despite the different nature of urban environments from other areas. In this study, therefore, more attention has been drawn to the urban geomorphological heritage assessment for urban geotourism development to fill this gap and development of Urban Geomorphological Heritage Research.

Khorramabad City has beautiful landscapes and valuable geomorphological potentials for tourist attraction and development of urban geotourism that have not been studied. Numerous geomorphological attractions such as several rivers, mountains, caves and erosional forms within urban area and its immediate surrounding territories have given the special beauty to the city. These potentials need recognition, inventory and assessment for urban geotourism/geoeducation purposes. Moreover, these attractions can play an important role in urban geotourism development of Khorramabad. Besides, inventory and assessment of geomorphological heritage in Khorramabad City proper and its extraterritorial jurisdiction for scientific, geotourism and educational uses are the main purposes of this research.

## Study Area

Khorramabad City is the 23rd most populous city of Iran and the centre of Lorestan province. According to the 2016 census of the Statistical Centre of Iran, the population of this city was 373,416 persons. The area of the city's proper is 38.5 $km^2$ and the area of the city's ETJ is 202.5 $km^2$. The extraterritorial jurisdiction of Khorramabad City is a designated buffer area located outside of the city proper, and Khorramabad Municipality is obliged to preserve these lands and to prevent irregular construction, according to the laws and regulations of the city's ETJ in Iran.

Khorramabad City has a semi-humid climate with warm summers and relatively cold winters with an average annual rainfall of 509 mm based on Iran Meteorological Organization data. The average elevation of the city is 1147 m above sea level and located in the west of Iran among the middle Zagros Mountains (Fig. 1). Khorramabad City has been developed on alluvial formations (alluvial plain and alluvial fan in geomorphology). Given that the study area lies within the folded Zagros structural zone, the folding phenomenon, as well as the major thrust faults, has played an important role in the morphology of the area. Tectonic forces also play a key role in the shaping of the region, and almost any changes in the sedimentary layers of the area have been influenced by tectonic factors (GSI,[1] 2013). The mountainous units around Khorramabad City also consist mainly of calcareous formations. Tectonic forces, especially in the Zagros Mountains, have led to the formation of major geological structures around Khorramabad, Khorramabad anticline and Khorramabad thrust fault, which are northwest-southeast. In this area, thrust faults have also been effective in creating mountains; for example, the Sefidkuh Mountain has been driven southwest by the Khorramabad thrust fault (GSI 2013). The morphology of Khorramabad City has been shaped under the influence of Khorramabad anticline as well as Khorramabad River which cut the axis of this anticline.

## Methods

To achieve the objectives of this study, the data presented in Table 1 have been used. The tools used include thematic maps (geology, topography, urban/land use), fieldwork tools (GPS,

[1] Geological Survey and Mineral Explorations of Iran

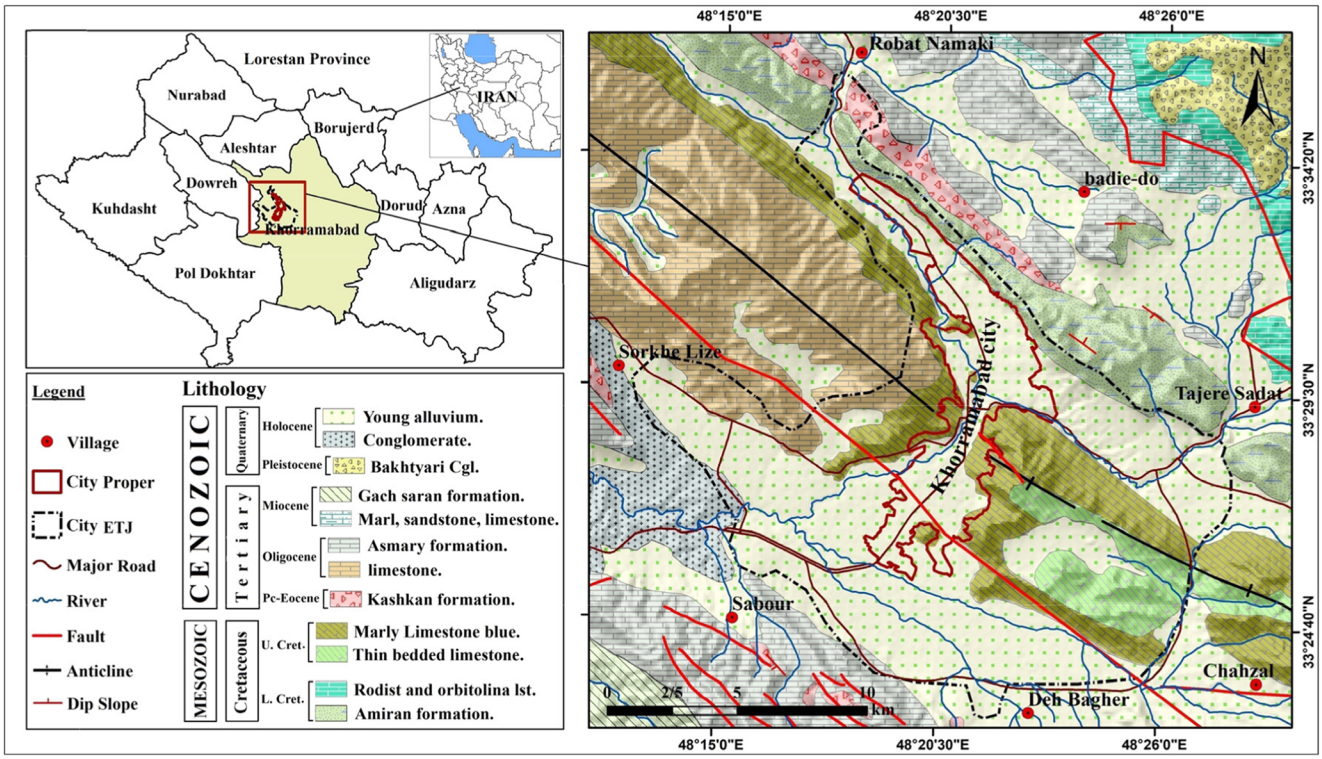


**Fig. 1** Location and geology of the study area

camera, identification form) and the ARC GIS 10.6 software for mapping.

Since the urban geomorphological heritage values have been overlooked by the public and even some sciences, it is very important to introduce the various potentials and values of geotourism, education, culture etc. In this regard, the use of assessment methods can be very helpful. Therefore, in this research, we have tried to use the Brilha's (2016) method as one of the comprehensive methods of geosite assessment and modifying (change and addition) that for urban geomorphosites assessment to achieve the objectives of the present study. The characteristics of urban areas are different from natural areas. Hence, assessment of geomorphosites needs indicators and parameters related to urban environments. For example, population density, accessibility, services and urban geodiversity in an urban area are different related to natural areas. Therefore, the parameters of these indicators need to be changed in order to clarify and appropriate assessment. In addition, geomorphosites in urban areas have been affected by diverse human activities; therefore, assessment of impacts requires the definition of relevant indicators and parameters. Our idea of modifying the Brilha's method for assessing urban geomorphological heritage is essentially an urban geomorphology approach so that the geomorphosite should represent urban geomorphological processes. In this regard, the method of Pralong (2005), Pica et al. (2017) and Reynard et al. (2016, 2017) and the natural and anthropogenic environment characteristics of the study area have been used. The general framework of the modified method is presented in Fig. 2.

**Table 1** List of data

| Data | Scale | Source |
|---|---|---|
| Geomorphology and geomorphosites | 25,000 and 2000 | Fieldwork in present study |
| DEM 10 m | 25,000 | National Cartographic Center of Iran |
| Road, urban/land use, city proper/extraterritorial jurisdiction (ETJ) | 25,000 and 2000 | Ministry of Roads and Urban Development of Iran |
| Geology | 25,000 and 100.000 | Geological Survey & Mineral Explorations of Iran (GSI) |
| Population data | - | Statistical Centre of Iran |
| Cultural places, national heritage | - | Ministry of Cultural Heritage, Tourism and Handicraft |
| Water sources (spring, river) | 25,000 | Iran Water Resources Management Company |

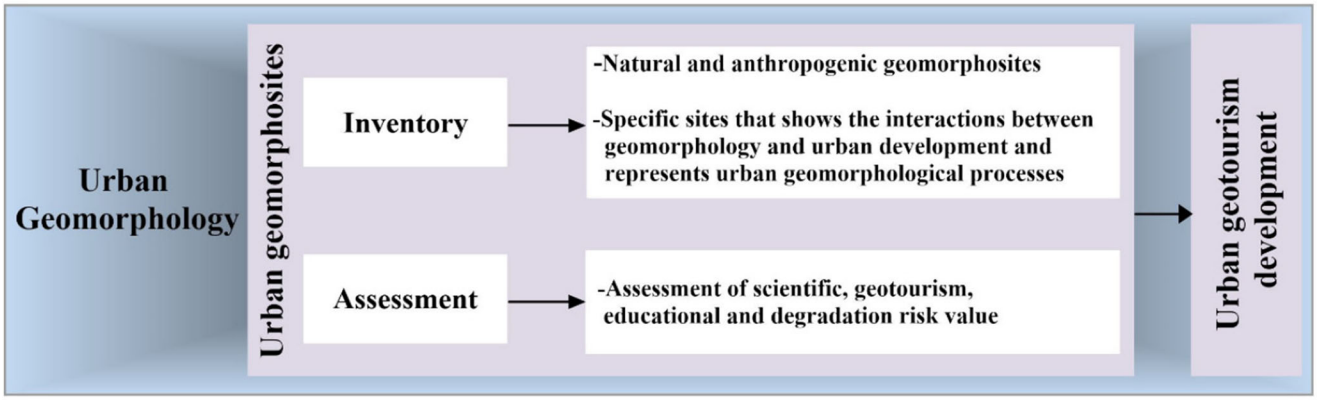


**Fig. 2** The general framework for inventory and assessment of urban geomorphological heritage

Our approach based on urban geomorphology consists of two parts: inventorying and assessing urban geomorphosites. In the first section, the geomorphosites in the area are inventoried, including natural, anthropogenic and specific sites that contribute to understanding the interactions between geomorphology and urban development and representing urban geomorphological processes. In the second part, the inventoried geomorphosites are assessment based on scientific, geotourism, educational and degradation risk criteria. The results can be used for urban geotourism development.

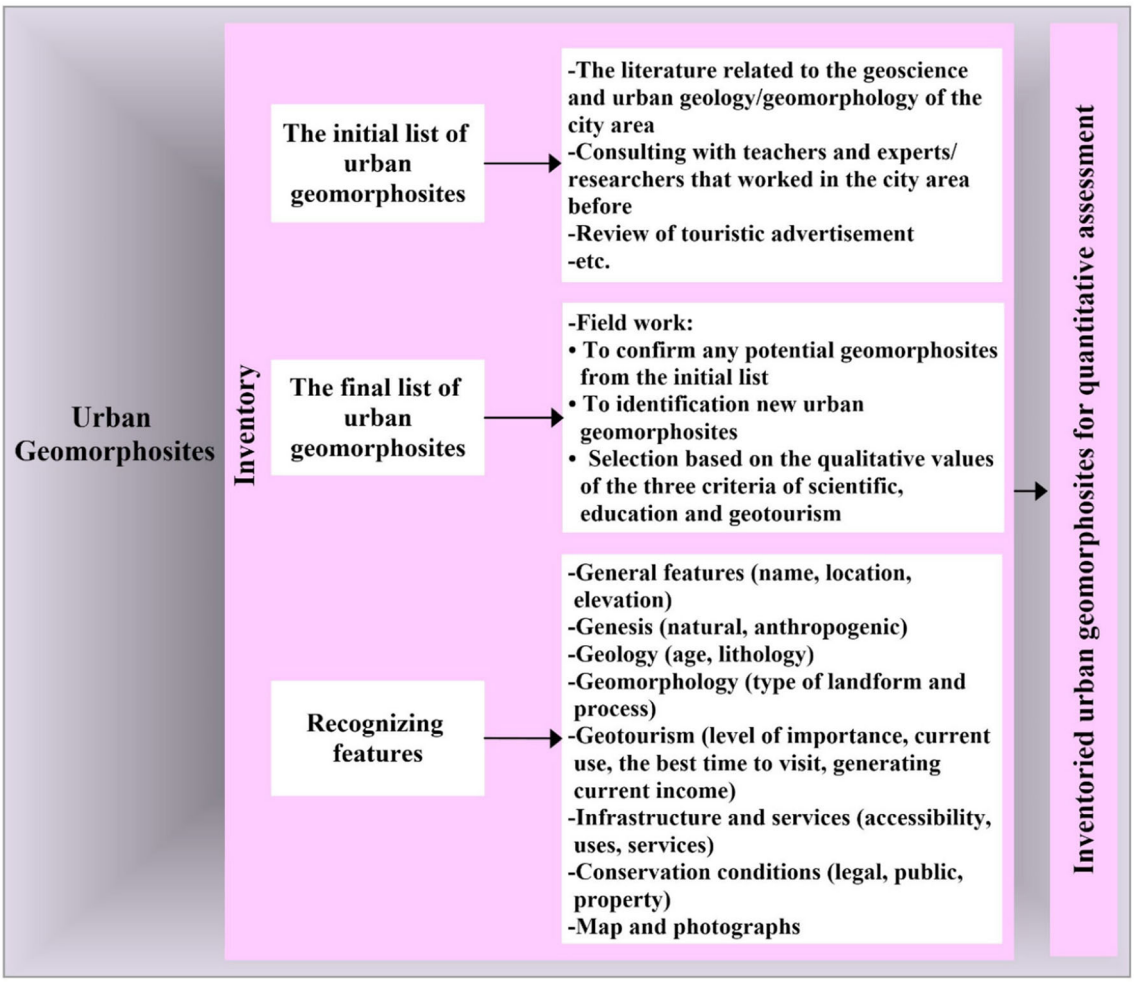


**Fig. 3** The general framework for inventory of urban geomorphological heritage (based on Brilha 2016 and Pralong 2005; Pica et al. 2017; Reynard et al. 2016, 2017)

## Inventory

The following steps have been performed for inventorying (based on Brilha 2016 and Pralong 2005; Pica et al. 2017; Reynard et al. 2016, 2017) (see Fig. 3).

Step 1 (the initial list of urban geomorphosites): This list is based on the literature related to the geoscience and urban geology/geomorphology with a focus on the study area, the comments/opinions from teachers holding field classes, consulting with experts/researchers that worked in the city area before and review of touristic advertisement (including tourism booklets, web pages, brochures and leaders).

Step 2 (the final list of urban geomorphosites): When the initial list of potential urban geomorphosites is completed, it is necessary to make it a definitive or final list of potential urban geomorphosites. To create a final list, it is necessary to do fieldwork for two main purposes: to confirm any potential geomorphosites from the list and finally identify new urban geomorphosites. To make the definitive and final selection of geomorphosites, their qualitative values need to be accepted according to the three criteria of scientific, education and geotourism, meaning that each geomorphosite that is capable of using at least two of the three scientific, educational and geotourism values is selected.

Step 3 (recognizing features): One of the important steps in the field survey and literature review is the recognition of general and specialized features to complete identification forms of urban geomorphosite. At this step, general information, genesis, geology, geomorphology, geotourism, infrastructure and services, the current conservation conditions of urban geomorphosite and its location map and photographs are provided.

## Assessment

In Brilha's (2016) method, each criterion has several indicators and each indicator has several parameters. In the modified method for the present study, the criteria and scores are following Brilha's (2016) method, but the indicators and parameters have been removed, added or changed for assessment of urban geomorphosites in Khorramabad City. In this method, quantitative assessment of geomorphosites has been carried out by using 4 criteria of scientific, education, geotourism and degradation risk. Eight indicators were used for quantitative assessment of the scientific criterion, 12 indicators for educational potential, 14 indicators for geotourism/recreational potential and 6 indicators for degradation risk. Geomorphosites scored 1 to 4 based on the parameters of each indicator. A geomorphosite can also get zero score. Each indicator receives different weights based on relative importance. These weights are essentially based on Brilha's (2016) method. The general framework of indicators and criteria for quantitative assessment of urban geomorphosites is presented in Fig. 4.

The criteria for assessing urban geomorphosites are calculated as follows. The criteria, indicators and parameters are presented in Tables 2, 3, 4 and 5, and the final scores in each criterion classified in four classes (see Table 6).

Scientific value of urban geomorphosites (SVUG): Indicators and parameters of scientific value assessment (Table 2) essentially emphasize the characteristics of urban geomorphology. The scientific value of each urban geomorphosite is calculated based on Eq. 1(for abbreviations, see Table 2). To clarify the concept of scores for the general public, the final score of each geomorphosite is expressed as a percentage.

$$\mathrm{SVUG} = \frac{\mathrm{RP} \times W + \mathrm{ER} \times W + \mathrm{SN} \times W + I \times W + \mathrm{UGD} \times W + R \times W + \mathrm{UL} \times W + \mathrm{UGH} \times W}{400} \times 100 \quad (1)$$

Educational value of urban geomorphosites (EVUG): The educational value is intended for the educational use of geomorphosites at different educational levels due to the variety of educational centres in cities; it is very important to identify geomorphosites with high educational potential. The educational value of each geomorphosite is calculated based on Eq. 2 (for abbreviations, see Table 3). Ten of the 12 defined educational indicators are shared with geotourism value, but they have got different weights (Table 3).

$$\mathrm{EVUG} = \frac{V \times W + A \times W + \mathrm{UL} \times W + S \times W + \mathrm{PD} \times W + \mathrm{AV} \times W + \mathrm{SB} \times W + U \times W + \mathrm{OC} \times W + C \times W + \mathrm{EP} \times W + \mathrm{UGD} \times W}{400} \times 100 \quad (2)$$

Geotourism value of urban geomorphosites (GVUG): A geomorphosite has high geotourism/recreational value when it has significant geomorphological elements, high aesthetic values and high value in other indicators (Table 4). The geotourism/

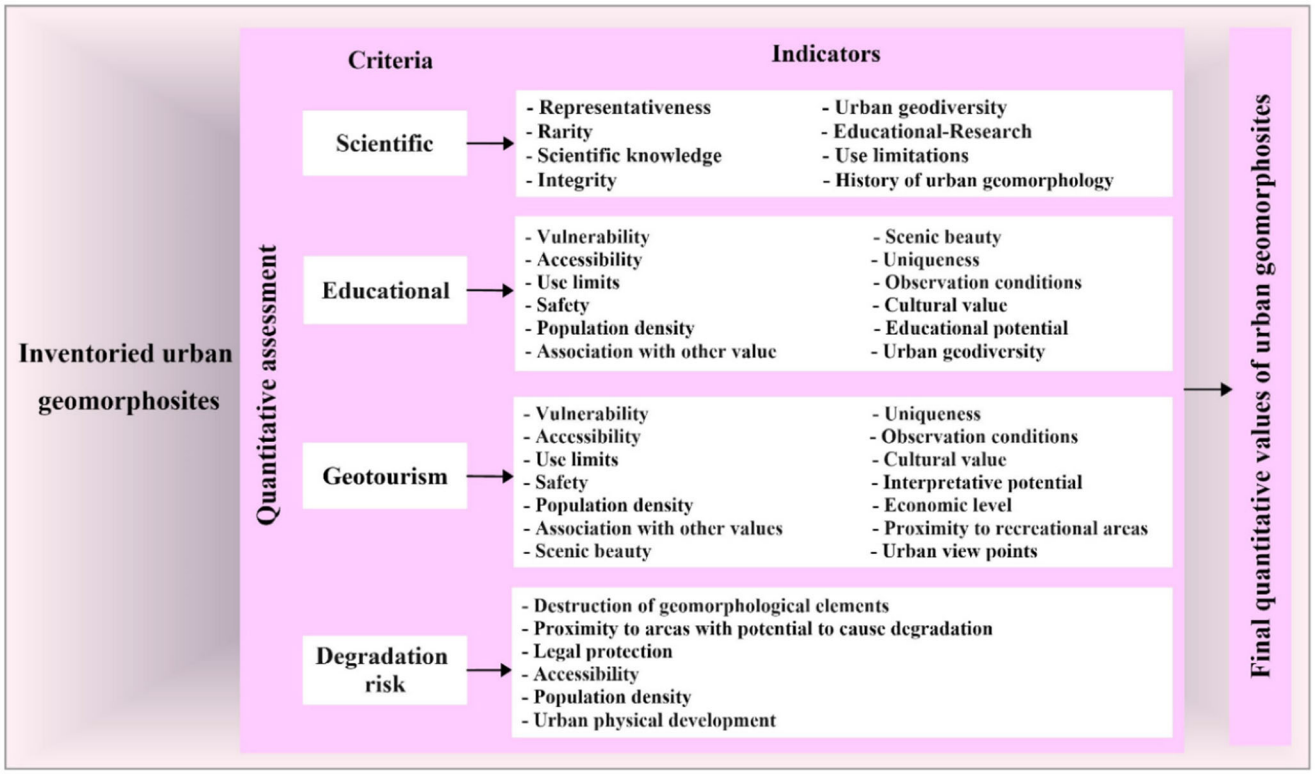


**Fig. 4** Criteria and indicators for assessment of urban geomorphosites (after Brilha 2016)

recreational value of each geomorphosite is calculated based on Eq. 3 (for abbreviations, see Table 4). Ten of the 14 defined geotourism/recreational indicators are shared with educational value but have got different weights. The reason for the commonality of the 10 indicators in geotourism/recreational and educational criteria is to conduct a comprehensive assessment of geomorphosites for both educational and geotourism/recreational uses separately. Due to different purposes, each of the indicators in the two geotourism/recreational and educational criteria has different weights and indicators; hence, the indicators and related parameters have been presented in separate tables.

$$\mathrm{GVUG} = \frac{V \times W + A \times W + \mathrm{UL} \times W + S \times W + \mathrm{PD} \times W + \mathrm{AV} \times W + \mathrm{SB} \times W + U \times W + \mathrm{OC} \times W + C \times W + \mathrm{IP} \times W + \mathrm{EL} \times W + \mathrm{PRA} \times W + \mathrm{UV} \times W}{400} \times 100 \quad (3)$$

Degradation risk value of urban geomorphosites (DRVUG): At the value of degradation risk, when there are possibilities of deterioration of all geomorphological elements by human factors, when geomorphosite located less than 50 m from areas with a potential degrading, when geomorphosite located in an area without legal protection and access control, when geomorphosite located less than 100 m from a paved road/urban street and with parking, and when located in a suitable area for urban physical development in less than next 5 years, gets the maximum score, but unlike other criteria, it is not in the positive direction, and the geomorphosite that gets the highest score for that criterion is a negative score. It is worth noting that accessibility and population density criteria have been used in geotourism, educational and destruction risk assessments. However, these criteria have been used in various respects. Appropriate access to geomorphosites for geotourism and educational use is considered an advantage for geomorphosite assessment while being considered a risk in terms of vulnerability (Brilha 2016). Degradation risk value is calculated based on Eq. 4 (for abbreviations, see Table 5).

$$\mathrm{DRVUG} = \frac{\mathrm{DGE} \times W + \mathrm{PADP} \times W + \mathrm{LP} \times W + A \times W + \mathrm{PD} \times W + \mathrm{UPD} \times W}{400} \times 100 \quad (4)$$

**Table 2** Indicators and parameters for the quantitative assessment of the scientific value of urban geomorphosites (after Brilha 2016, with changes)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| Representation (RP) | | 20 |
| The geomorphosite is the best example at the international/national level to illustrate elements or processes related to urban geomorphology | 4 | |
| The geomorphosite is the best example in the region to illustrate elements or processes related to urban geomorphology | 3 | |
| The geomorphosite reasonably illustrates elements or processes related to urban geomorphology | 2 | |
| The geomorphosite illustrates only elements or processes related to geomorphology | 1 | |
| Educational research (ER) | | 15 |
| The geomorphosite is visited by international universities, institutes and schools related to geosciences | 4 | |
| The geomorphosite is visited by national universities, institutes and schools related to geosciences | 3 | |
| The geomorphosite is visited by provincial universities, institutes and schools related to geosciences. | 2 | |
| The geomorphosite is visited by the city's universities, institutes and schools related to geosciences | 1 | |
| Scientific knowledge (SN) | | 5 |
| There are articles about this geomorphosite in international scientific journals related to geosciences | 4 | |
| There are articles about this geomorphosite in national scientific journals related to geosciences | 3 | |
| There are some abstracts about this geomorphosite in international scientific journals related to geosciences | 2 | |
| There are some abstracts about this geomorphosite in national scientific journals related to geosciences | 1 | |
| Integrity (*I*) | | 15 |
| The geomorphosite and its main geomorphological elements have been very well preserved | 4 | |
| The geomorphosite is not very well preserved itself but its main geomorphological elements are still preserved | 3 | |
| The geomorphosite is not well preserved and its main geomorphological elements have been damaged | 2 | |
| The geomorphosite has a conservation problem and its main geomorphological elements have been completely altered and modified | 1 | |
| Urban geodiversity (UGD) | | 5 |
| The geomorphosite has more than 5 types of specific urban geodiversity elements with scientific relation | 4 | |
| The geomorphosite has 4 or 5 types of specific urban geodiversity elements with scientific relation | 3 | |
| The geomorphosite has 2 or 3 types of specific urban geodiversity elements with scientific relation | 2 | |
| The geomorphosite has 1 type of specific urban geodiversity element with scientific relation | 1 | |
| Rarity (*R*) | | 15 |
| The geomorphosite is the only type in the study city (related to urban geomorphology) | 4 | |
| There are 1 to 2 similar geomorphosite samples in the study city (related to urban geomorphology) | 3 | |
| There are 3 to 4 similar geomorphosite samples in the study city (related to urban geomorphology) | 2 | |
| There are more than 4 similar geomorphosite samples in the study city (related to urban geomorphology) | 1 | |
| Use limitation (UL) | | |
| The geomorphosite has no limitation (legal permission, natural/human obstacles) for sampling and fieldwork | 4 | 10 |
| After overcoming the limitations, it is possible to collect data and perform fieldwork | 3 | |
| The geomorphosite has a time limit for sampling and fieldwork (such as an ancient site) | 2 | |
| It is difficult to collect data and perform fieldwork due to the difficulty of overcoming difficulties and limitations | 1 | |
| History urban geomorphology (UGH) | | 15 |
| The geomorphosite is the best example of reconstructing the urban geomorphology history in the study city | 4 | |
| The geomorphosite is a good example of reconstructing the urban geomorphology history in the study city | 3 | |
| The geomorphosite shows some elements of the urban geomorphology history in the study city | 2 | |
| The geomorphosite only shows the history of geomorphology | 1 | |

## Results

### Result of Urban Geomorphological Heritage Inventory

Based on the inventory method, 32 geomorphosites were inventoried (Fig. 5 and Table 7) and their characteristics were recorded in the identification form (Fig. 6). Geomorphosites mainly consist of karstic geomorphosites (such as caves, springs and springheads, natural arch), fluvial geomorphosites related to water/river flow (such as waterfalls, cluses and valleys), tectonic geomorphosites (such as mountains, folds and escarpment), anthropogenic geomorphosites (such as natural-artificial lake, stone pond, stone inscription and ancient hills) and specific geomorphosites (such as Falak-ol-Aflak Castle Hill and Khorramabad River-Shapuri Bridge). These geomorphosites are mainly along the Khorramabad Valley and the main rivers (Robat and Khorramabad) that flow in this valley, which shows a linear pattern like the shape of Khorramabad City. The geomorphosite density in the central part of the city is higher than in other parts.

Khorramabad is formed in a valley with a beautiful landscape (Fig. 7a). Tectonic and erosion processes have led to the formation of beautiful eroded mountains and anticlines in the study area. One of the most prominent of these geomorphosites is the Maxmalkuh Mountain (Fig. 7b) and its geosites that extend along the northeast side of Khorramabad. This name is due to the vast lichen cover of this mountain. Also, it has beautiful and unique canyons and erosion forms. Another important geomorphosite is the

**Table 3** Indicators and parameters for the quantitative assessment of the educational value of urban geomorphosites (after Brilha 2016, with changes)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| Vulnerability (*V*) | | 10 |
| It is not possible to destroy the geomorphological elements of the geomorphosite through anthropic activity | 4 | |
| It is possible to destroy the secondary geomorphological elements of geomorphosite through anthropic activity | 3 | |
| It is possible to destroy the main geomorphological elements of geomorphosite through anthropic activity | 2 | |
| It is possible to destroy all the geomorphological elements of the geomorphosite through anthropic activity | 1 | |
| Accessibility (*A*) | | 10 |
| Direct access to geomorphosite is possible with both public and private transport vehicles and has bus parking | 4 | |
| Direct access to geomorphosite is possible with personal vehicles and has parking | 3 | |
| There is direct access to geomorphosite with personal vehicles but there is no parking nearby | 2 | |
| There is no direct access with vehicles, but walking is possible | 1 | |
| Use limitation (UL) | | 5 |
| The geomorphosite has no limitations on use by students and tourists | 4 | |
| The geomorphosite can occasionally be used by students and tourists | 3 | |
| The geomorphosite can be used after overcoming the limitations (legal permission, natural/human obstacles) | 2 | |
| It is very difficult to use geomorphosite by students and tourists due to problems and limitations | 1 | |
| Safety (*S*) | | 10 |
| The geomorphosite has safety facilities (fence, stairs) and is within 1 km of the emergency | 4 | |
| The geomorphosite has safety facilities (fence, stairs) and is within 5 km of the emergency | 3 | |
| The geomorphosite has no safety facilities (fence, stairs) but is within 1 km of the emergency | 2 | |
| The geomorphosite has no safety facilities (fence, stairs) but is within 5 km of the emergency | 1 | |
| Population density (PD) | | 5 |
| The geomorphosite is located in an urban district with more than 200 persons per hectare | 4 | |
| The geomorphosite is located in an urban district with 150 to 200 persons per hectare | 3 | |
| The geomorphosite is located in an urban district with 100 to 150 persons per hectare | 2 | |
| The geomorphosite is located in an urban district with less than 100 persons per hectare | 1 | |
| Association to other values (AV) | | 5 |
| The occurrence of several cultural and ecological values within less than 1 km of geomorphosite | 4 | |
| The occurrence of several cultural and ecological values within less than 5 km of geomorphosite | 3 | |
| The occurrence of a cultural and an ecological value within less than 5 km of geomorphosite | 2 | |
| The occurrence of an ecological or a cultural value within less than 5 km of geomorphosite | 1 | |
| Scenic beauty (SB) | | 5 |
| The geomorphosite is currently used as a tourist destination on international and national trips | 4 | |
| The geomorphosite is occasionally used as a tourist destination on national trips | 3 | |
| The geomorphosite is currently used as a tourist destination on local trips | 2 | |
| The geomorphosite is occasionally used as a tourist destination on local trips | 1 | |
| Uniqueness (*U*) | | 5 |
| The geomorphosite shows unique features compared with the country and neighbouring countries | 4 | |
| The geomorphosite shows unique features compared with the province and neighbouring provinces | 3 | |
| The geomorphosite shows unique features compared with the city and neighbouring cities | 2 | |
| The geomorphosite shows relatively common features throughout the city and neighbouring cities | 1 | |
| Observation conditions (OC) | | 10 |
| All geomorphological elements of the geomorphosite are visible at very good conditions | 4 | |
| There are obstacles in the landscape that makes it difficult to observe some geomorphological elements of the geomorphosite | 3 | |
| There are obstacles in the landscape that makes it difficult to observe the main geomorphological elements of the geomorphosite | 2 | |
| There are obstacles in the landscape that prevents the full observation of the main geomorphological elements | 1 | |
| Cultural value (CV) | | 5 |
| The geomorphosite has more than 3 types of religious, historical, artistic, literary values and so on | 4 | |
| The geomorphosite has 3 types of religious, historical, artistic, literary values and so on | 3 | |
| The geomorphosite has 2 types of religious, historical, artistic, literary values and so on | 2 | |
| The geomorphosite has 1 type of religious, historical, artistic, literary values and so on | 1 | |
| Educational potential (EP) | | 20 |

**Table 3** (continued)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| The geomorphosite shows geomorphological elements that can be taught in all educational levels | 4 | |
| The geomorphosite shows the geomorphological elements that can be taught in elementary school | 3 | |
| The geomorphosite shows the geomorphological elements that can be taught in secondary | 2 | |
| The geomorphosite shows the geomorphological elements that can be taught in university | 1 | |
| Urban geodiversity (UGD) | | 10 |
| There are more than 5 types of urban geodiversity elements within less than 500 m of the geomorphosite | 4 | |
| There are 4 or 5 types of urban geodiversity elements within less than 500 m of the geomorphosites | 3 | |
| There are 2 or 3 types of urban geodiversity elements within less than 500 m of the geomorphosites | 2 | |
| There is only 1 type of urban geodiversity element within less than 500 m of geomorphosite | 1 | |

Sefidkuh Mountain (Fig. 7c). This geomorphosite from the west has restricted urban development of Khorramabad. Due to limestone formations, Sefidkuh is the best site to visit variety karst landforms, such as cave, karen and karst spring. Opposite Sefidkuh is Modbe Mountain and has restricted urban development in the east of Khorramabad. This geomorphosite is known as the roof of the city (Fig. 7d).

In Khorramabad City, there are two Kargane and Robat Rivers, which meeting in the centre of the city, forming the Khorramabad River that flows from the centre to the south of the city. The Robat River flows through a deep valley called Shabixun Cluse in the north of the city. Along these rivers, numerous bridges have been built with local stones in the past, among them are the two important and historical bridges of Shapuri and Safavi. Also, the city of Khorramabad has been developed along these rivers. Two locations along the rivers (Khorramabad River-Shapuri Bridge and Kargane River) as specific sites are shown in Fig. 8a, b. These sites indicate the interaction between geomorphology and urban development of Khorramabad. In the centre of the city, the Falak-ol-Aflak Hill with a historical castle on it is one of the other specific sites. The height of the hill is about 40 m from the adjacent streets level, taking into account the height of the castle walls, so it overlooks the whole city (Fig. 8c). Also, there are several lakes in the city that give a beautiful view. The most important of these is the natural-artificial lake of Kiyo (Fig. 8d), one of the most beautiful tourist destinations in Khorramabad. This lake covers 7 ha and its depth varies from 3 to 7 m.

Other urban geomorphosites include Absharan Valley (Fig. 9d) and Park-e Jangali Valley (Fig. 9f), which are located on the northeast side of the city with an erosional and beautiful landscape. In the Absharan Valley, waterfalls and ponds are formed, the most important of which is known as the Tallaei Waterfall (Fig. 9a). Sangsila Natural Arch (Fig. 9b) and Hoze-e Musa Valley (Fig. 9c) are also in the east of Khorramabad. The dissolution and weathering of limestone have led to the creation of a large natural big arch known to the general public as the bust of a horse lying on the ground. This natural arch is the largest in the study area and formed with a regular layering of limestone. In addition, there are several karst springs in the Khorramabad City proper that are perennial and have pond and stream/rivulet. These springs include Shahva Spring, Golestan Spring, Gerdab-e Sangi Stone Pond, and Nilufar Pond. The dominant lithology of these springs is limestone. The main cause of water outflow from these formations is fractures (joints and faults), dissolution and karstification. The Golestan Spring flows as several springs from beneath the hill on which the Falak-ol-Aflak Castle is built. The water flows into the Khorramabad River through several streams/rivulets. The Gerdab-e Sangi Stone Pond emanates from calcareous formations and the building of this spring, which is cylindrical and is made of stone and mortar, is one of the ancient monuments of the city. Caves are among the geomorphosites of Khorramabad. The most important of these are the Qamari and the Kaldar Caves. The Qamari Cave (see Fig. 6), overlooking the Gerdab-e Sangi Stone Pond (Fig. 9g), has two limestone halls and forms of stalactite and stalagmite. The Kaldar Cave is also one of the historical caves of Khorramabad Valley, which, according to archaeological excavations, dating back to around 54,000 years ago (see Bazgir et al. 2017).

Other geomorphosites are also presented in Table 7, but what distinguishes some of the geomorphosites in Khorramabad for the development of urban geotourism is not only their geological/geomorphological values but the fascinating myths, stories and historical facts about a number of these works. For example, the name of the geomorphosite of the Hoze-e Musa derives from the belief that Moses was first stepped on the site and then created a pool there. There is also a small inscription at the top of the pond. Another example is the Falak-ol-Aflak Castle, dating back to the Sassanid era (Sasanian Empire in Iran, from 224 to 651 AD). The reason for the construction of the castle at that time, in addition to the height of the hill on which the castle is built, is the presence of the Golestan Spring just below the ancient hill at that time and even now considered one of the most water-rich springs of the

**Table 4** Indicators and parameters for the quantitative assessment of geotourism value of urban geomorphosites (after Brilha 2016, with changes)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| Vulnerability (*V*) | | 10 |
| It is not possible to destroy the geomorphological elements of the geomorphosite through anthropic activity | 4 | |
| It is possible to destroy the secondary geomorphological elements of geomorphosite through anthropic activity | 3 | |
| It is possible to destroy the main geomorphological elements of geomorphosite through anthropic activity | 2 | |
| It is possible to destroy all the geomorphological elements of the geomorphosite through anthropic activity | 1 | |
| Accessibility (*A*) | | 5 |
| Direct access to geomorphosite is possible with both public and private transport vehicles and has bus parking | 4 | |
| Direct access to geomorphosite is possible with personal vehicles and has parking | 3 | |
| There is direct access to geomorphosite with personal vehicles but there is no parking nearby | 2 | |
| There is no direct access with vehicles, but walking is possible | 1 | |
| Use limitation (UL) | | 5 |
| The geomorphosite has no limitations on use by students and tourists | 4 | |
| The geomorphosite can occasionally be used by students and tourists | 3 | |
| The geomorphosite can be used after overcoming the limitations (legal permission, natural/human obstacles) | 2 | |
| It is very difficult to use geomorphosite by students and tourists due to problems and limitations | 1 | |
| Safety (*S*) | | 5 |
| The geomorphosite has safety facilities (fence, stairs) and is within 1 km of the emergency | 4 | |
| The geomorphosite has safety facilities (fence, stairs) and is within 5 km of the emergency | 3 | |
| The geomorphosite has no safety facilities (fence, stairs) but is within 1 km of the emergency | 2 | |
| The geomorphosite has no safety facilities (fence, stairs) but is within 5 km of the emergency | 1 | |
| Population density (PD) | | 5 |
| The geomorphosite is located in an urban district with more than 200 persons per hectare | 4 | |
| The geomorphosite is located in an urban district with 150 to 200 persons per hectare | 3 | |
| The geomorphosite is located in an urban district with 100 to 150 persons per hectare | 2 | |
| The geomorphosite is located in an urban district with less than 100 persons per hectare | 1 | |
| Association to other values (AV) | | 5 |
| The occurrence of several cultural and ecological values within less than 1 km of geomorphosite | 4 | |
| The occurrence of several cultural and ecological values within less than 5 km of geomorphosite | 3 | |
| The occurrence of a cultural and an ecological value within less than 5 km of geomorphosite | 2 | |
| The occurrence of an ecological or a cultural value within less than 5 km of geomorphosite | 1 | |
| Scenic beauty (SB) | | 10 |
| The geomorphosite is currently used as a tourist destination on international and national trips | 4 | |
| The geomorphosite is occasionally used as a tourist destination on national trips | 3 | |
| The geomorphosite is currently used as a tourist destination on local trips | 2 | |
| The geomorphosite is occasionally used as a tourist destination on local trips | 1 | |
| Uniqueness (*U*) | | 15 |
| The geomorphosite shows unique features compared with the country and neighbouring countries | 4 | |
| The geomorphosite shows unique features compared with the province and neighbouring provinces | 3 | |
| The geomorphosite shows unique features compared with the city and neighbouring cities | 2 | |
| The geomorphosite shows relatively common features throughout the city and neighbouring cities | 1 | |
| Observation conditions (OC) | | 10 |
| All geomorphological elements of the geomorphosite are visible at very good conditions | 4 | |
| There are obstacles in the landscape that makes it difficult to observe some geomorphological elements of the geomorphosite | 3 | |
| There are obstacles in the landscape that makes it difficult to observe the main geomorphological elements of the geomorphosite | 2 | |
| There are obstacles in the landscape that prevents the full observation of the main geomorphological elements | 1 | |
| Cultural value (CV) | | 5 |
| The geomorphosite has more than 3 types of religious, historical, artistic, literary values and so on | 4 | |
| The geomorphosite has 3 types of religious, historical, artistic, literary values and so on | 3 | |
| The geomorphosite has 2 types of religious, historical, artistic, literary values and so on | 2 | |
| The geomorphosite has 1 type of religious, historical, artistic, literary values and so on | 1 | |
| Interpretation potential (IP) | | 5 |

**Table 4** (continued)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| The geomorphosite presents the geomorphological elements in a very clear and expressive way to the general public | 4 | |
| To understand the geomorphological elements of geomorphosite, the general public needs some geomorphological background | 3 | |
| To understand the geomorphological elements of geomorphosite, the general public needs a solid geomorphological background | 2 | |
| Geomorphosite presents the geomorphological elements that can only be understood by geomorphological experts | 1 | |
| Economic level (EL) | | 5 |
| The geomorphosite is located in an urban district where the household income at least the double of the national average | 4 | |
| The geomorphosite is located in an urban district where the household income higher than the national average | 3 | |
| The geomorphosite is located in an urban district where the household income similar to the national average | 2 | |
| The geomorphosite is located in an urban district where the household income lower than the national average | 1 | |
| Proximity to recreational areas (PRA) | | 5 |
| Geomorphosite located less than 2 km from recreational areas or tourist attractions | 4 | |
| Geomorphosite located less than 5 km from recreational areas or tourist attractions | 3 | |
| Geomorphosite located less than 10 km from recreational areas or tourist attractions | 2 | |
| Geomorphosite located less than 20 km from recreational areas or tourist attractions | 1 | |
| Urban viewpoints (UV) | | 10 |
| The geomorphosite has more than 6 different viewpoints from the urban landscape | 4 | |
| The geomorphosite has 6 or 5 different viewpoints from the urban landscape | 3 | |
| The geomorphosite has 4 or 3 different viewpoints from the urban landscape | 2 | |
| The geomorphosite has 1 or 2 different viewpoints from the urban landscape | 1 | |

city. Formerly used as a prison, the castle has now become a place for tourists to visit because of its beautiful landscape and location, as well as its museums. Another example is the Kaldar Cave, which excavations at the site led to the discovery of cultural remains generally associated with anatomically modern humans and evidence of a probable Neanderthal-made industry (Bazgir et al. 2017). Another example is Shabixun Cluse (Fig. 9e), named after a historical event on it. The incident is related to a surprise raid on the forces of King Abbas Safavi by the then ruler of Lorestan (around 1600 AD) who came to the area to crush him.

## Results of Urban Geomorphological Heritage Assessment

The final results of the scientific, educational, tourist and degradation risk criteria assessment are presented in Tables 8, 9, 10 and 11. Quantitative assessment of the geomorphosites based on Brilha's (2016) method that modified in this study for urban geomorphosites of Khorramabad indicate that in the scientific criterion, Falak-ol-Aflak Castle Hill received the highest score (93.75) and was ranked first. One of the most important reasons is that this geomorphosite is the best example for illustrating elements or processes related to urban geomorphology, visited by international universities, institutes and schools related to geosciences. Moreover, there are articles about this geomorphosite in international scientific journals related to geosciences. This geomorphosite has more than 5 types of urban geodiversity elements with scientific relevance. It is the only type in the study city (related to urban geomorphology) and is ultimately the best example for reconstructing the history of urban geomorphology as a specific site in the study city. The geomorphosites of Maxmalkuh Mountain with a score of 92.5, Kaldar Cave with a score of 82.5 and Modbe Mountain with a score of 76.25 are in the scientific rankings respectively. In general, the results showed that from all geomorphosites, 4 are very high, 18 are high and 10 are moderate in terms of scientific value (see Table 8). Maxmalkuh, Modbe and Sefidkuh Mountains are natural sites, but due to the restrictions they have created for urban development in Khorramabad and helping to understand the interactions between geomorphology and urban development, they have been introduced as natural-specific sites (N and S in Table 8). Also, types of natural, anthropogenic and specific sites are mentioned for other geomorphosites in Table 8.

In terms of educational criterion, the Falak-ol-Aflak Castle Hill geomorphosite with a score of 92.5 is ranked first. The most important reasons are easy and quick access to this geomorphosite, high safety, proximity and association to other values such as Khorramabad River, Safavi Historical Bridge and Golestan Spring, beauty scenic/landscape, good visit conditions from all over the city due to its centrality, its height and cultural value. The geomorphosites of Khorramabad River-Shapuri Bridge with a score of 88.75, Maxmalkuh with a score of 87.5 and Khorramabad River-Safavi Bridge with a score of 86.25 respectively are ranked next. The educational

**Table 5** Indicators and parameters for the quantitative assessment of degradation risk value of urban geomorphosites (after Brilha 2016, with changes)

| Indicators and parameters | Score | Weight (*W*) |
|---|---|---|
| Destruction of geomorphological elements (DGE) | | 35 |
| There are possibilities of deterioration of all geomorphological elements by human factors | 4 | |
| There are possibilities of deterioration of the main geomorphological elements by human factors | 3 | |
| There are possibilities of deterioration of secondary geomorphological elements by human factors | 2 | |
| There are the minor possibility of deterioration of secondary geomorphological elements by human factors | 1 | |
| Proximity to areas with potential to cause degradation (PAPD) | | 15 |
| Geomorphosite located less than 50 m from areas with a potential degrading | 4 | |
| Geomorphosite located less than 200 m from areas with a potential degrading | 3 | |
| Geomorphosite located less than 500 m from areas with a potential degrading | 2 | |
| Geomorphosite located less than 1000 m from areas with potential degrading | 1 | |
| Legal protection (LP) | | 20 |
| Geomorphosite located in an area without legal protection and access control | 4 | |
| Geomorphosite located in an area without legal area but with access control | 3 | |
| Geomorphosite located in an area with legal protection but without access control | 2 | |
| Geomorphosite located in an area with legal protection and access control | 1 | |
| Accessibility (*A*) | | 10 |
| Geomorphosite located less than 100 m from a paved road/urban street and with parking | 4 | |
| Geomorphosite located less than 500 m from a paved road/urban street and with parking | 3 | |
| Geomorphosite accessible by vehicles through city alleys/gravel road | 2 | |
| Geomorphosite accessible through walking more than 200 m | 1 | |
| Population density (PD) | | 5 |
| Geomorphosite located in an urban district with more than 200 persons per hectare | 4 | |
| Geomorphosite located in an urban district with 150 to 200 persons per hectare | 3 | |
| Geomorphosite located in an urban district with 100 to 150 persons per hectare | 2 | |
| Geomorphosite located in an urban district with less than 100 persons per hectare | 1 | |
| Urban physical development (UPD) | | 15 |
| Geomorphosite located in a suitable area for urban physical development in less than next 5 years | 4 | |
| Geomorphosite located in a suitable area for urban physical development in less than next 10 years | 3 | |
| Geomorphosite located in a suitable area for urban physical development in less than next 20 years | 2 | |
| Geomorphosite located in a suitable area for urban physical development in less than next 50 years | 1 | |

values of other geomorphosites are presented in Table 9. What is important is that these urban geomorphosites have the appropriate potential for educational use, due to the presence and activity of various educational centres in Khorramabad City, such as elementary and secondary schools and universities.

**Table 6** The classification of the final scores in each criterion

| Criteria | Classification |
|---|---|
| Scientific Geotourism Educational Degradation Risk Final score (percent) | |
| ≤ 25 | Low |
| 26–50 | Moderate |
| 51–75 | High |
| 76–100 | Very High |

According to geotourism criterion, Falak-ol-Aflak Castle Hill similar to scientific and educational criteria has the highest score (83.75). Its reasons include easy and convenient access to geomorphosite, high safety and the presence of several cultural and ecological values in its proximity, the beauty of the landscape, good observation conditions and showing unique features compared with the country. Also, this geomorphosite illustrates geomorphological elements in a very clear and expressive manner to the general public and is less than 1 km from recreational or tourist attractions such as the city park, the Khorramabad River and the Safavi Historical Bridge. Also, there are more than 6 different viewpoints of the urban landscape. After that, geomorphosites of Kiyo Lake with a score of 82.5, Khorramabad River-Safavi Bridge with a score of 77.5, Khorramabad River-Shapuri Bridge with a score of 75 and Maxmalkuh Mountain with a score of 73.75 are in next ranks. In contrast, Gilvaran Cave with a score of

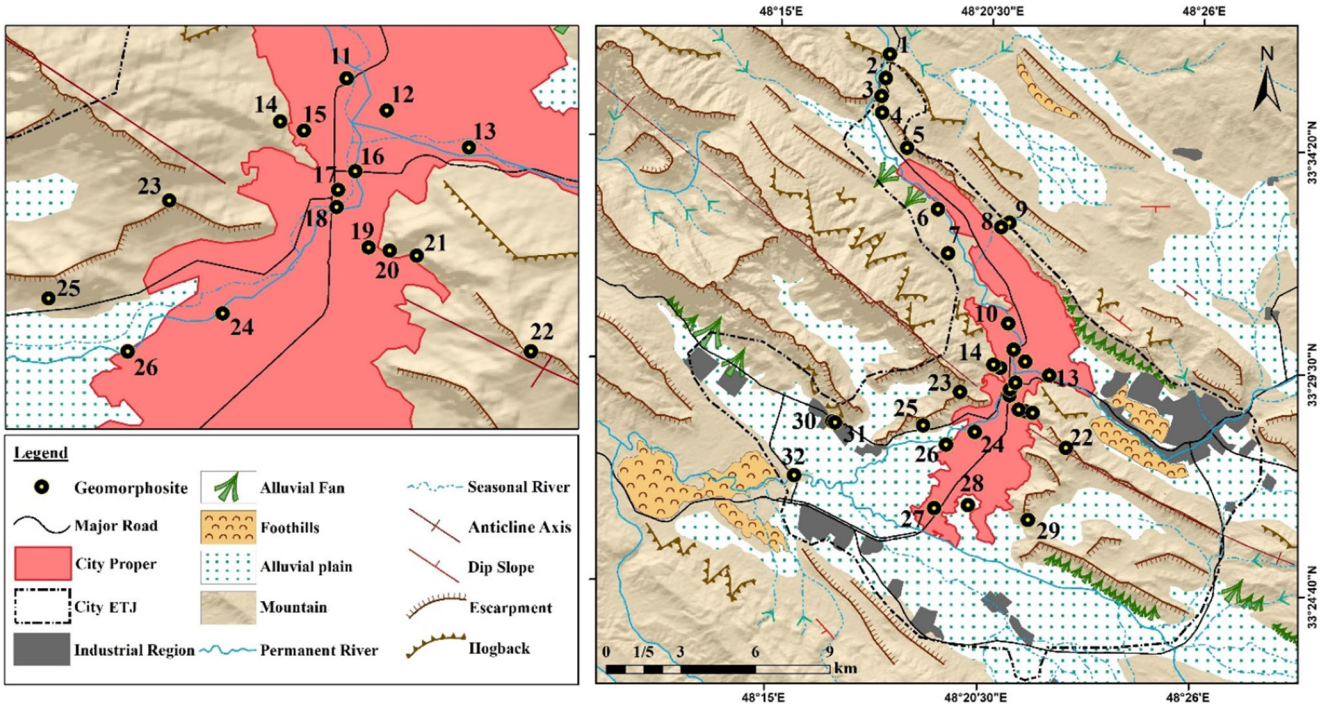


**Fig. 5** Geomorphological units and geomorphosites (see names in Table 7)

33.75, Mahibazan Colored Outcrop with a score of 38.75 and Hoze-e Musa with a score of 40 received the lowest rank respectively (Table 10). These geomorphosites are in the lowest ranks due to low score of observation conditions, use limitation, accessibility, urban viewpoints and other indicators of geotourism criterion.

The results of the assessment and classification of degradation risk value showed that the highest level of degradation risk is related to the Absharan Valley geomorphosite with a score of 88.75. The main reasons are the geomorphosite located less than 50 m from areas with a potential degrading, located less than 100 m from a paved road/urban street and with parking and located in a suitable area for urban physical development in less than next 10 years. The lowest degradation risk is related to the geomorphosite of Gilvaran Cave with a score of 28.75. The reasons are the high distance from potential destruction area and low possibility of destruction of its geomorphological elements, legal protection of the geomorphosite and access control and low population density in proximity to this geomorphosite. Among the investigated geomorphosites, 7 are at very high degradation risk, 16 at high degradation risk, 9 are at medium degradation risk and none of the geomorphosites are at low degradation risk. Therefore, among the total of 32 geomorphosites assessed in terms of degradation risk, only 9 are in a more balanced condition and the other 23 geomorphosites require attention and protection (Table 11).

**Table 7** Names of geomorphosites shown in Fig. 5

| Number on the map | Geomorphosite name | Number on the map | Geomorphosite name | Number on the map | Geomorphosite name |
|---|---|---|---|---|---|
| 1 | Mahibazan Folds | 12 | Shahva Spring and Rivulet | 23 | Sefidkuh Mountain |
| 2 | Mahibazan Colored Outcrop | 13 | Kargane River | 24 | Khorramabad River-Shapuri Bridge |
| 3 | Shabixun Cluse | 14 | Qamari Cave | 25 | Gilvaran Cave |
| 4 | Park-e Jangali Valley | 15 | Gerdab-e Sangi Stone Pond | 26 | Khorramabad River-Goldasht |
| 5 | Maxmalkuh Mountain | 16 | Khorramabad River-Safavi Bridge | 27 | Masur Hill |
| 6 | Robat River | 17 | Hill of Falak-ol-Aflak Castle | 28 | Peleborj Hill |
| 7 | Kaldar Cave | 18 | Golestan Spring and Rivulet | 29 | Konji Cave |
| 8 | Absharan Valley | 19 | Khorramabad Stone Encryption | 30 | Nilufar Pond |
| 9 | Tallaei Waterfall | 20 | Sangsila Natural Arch | 31 | Changaie Karstic Collection |
| 10 | Kiyo Lake | 21 | Hoze-e Musa Valley | 32 | Khorramabad River-Cham Anjir |
| 11 | Khorramabad Rocky Park | 22 | Modbe Mountain | | |

| General Features | | | |
|---|---|---|---|
| **Name:** Qamari Cave | **Coordinates:** **Y:** 33.492599 **X:** 48.345809 | **location:** West of Khorramabad city, Takhti District | **Altitude of the sea level:** 1287 meters |
| **Genesis** | | | |
| **Type:** Karstic - Dissolution of carbonate sedimentary rock | | **Classification (Natural/Anthropogenic/Specific Site):** Natural | |
| **Geology** | | | |
| **Geological age:** Upper Cretaceous | | **Lithology Type:** Limestone | |
| **Geomorphology** | | | |
| **Process Type:** Karstic | **Landform Type:** Cave | **Neighboring Landforms:** Cave, Valley, Escarpment, Stone Pond, Etc. | **Research Field:** Geotourism, Geoarchaeological, Karst Geomorphology |
| **Geotourism** | | | |
| **Importance Level:** National | **Current Tourism/Recreational Uses:** Used by tourist and local people | **The best time to visit:** Spring and Summer | **Generating Current Income:** Without Current Income |
| **Infrastructure and Service** | | | |
| **Accessibility:** Paved Road then Walking | **Urban/Land use:** Residential, Greenspace | | **Services:** Without services |
| **Conservation Condition** | | | |
| **Legal Conservation:** Without conservation | **Public Use:** Used by the public | | **Property Type:** Public |
| **Map and Photographs** | | | |

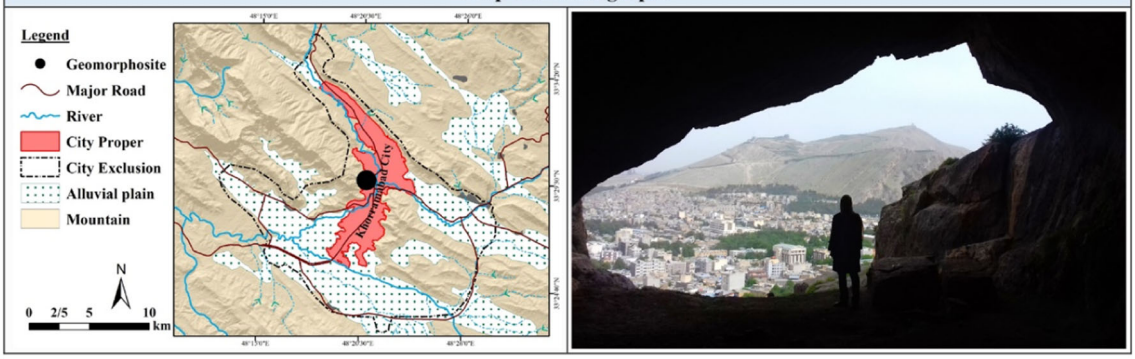


**Fig. 6** The sample of identification form that completed for all urban geomorphosites

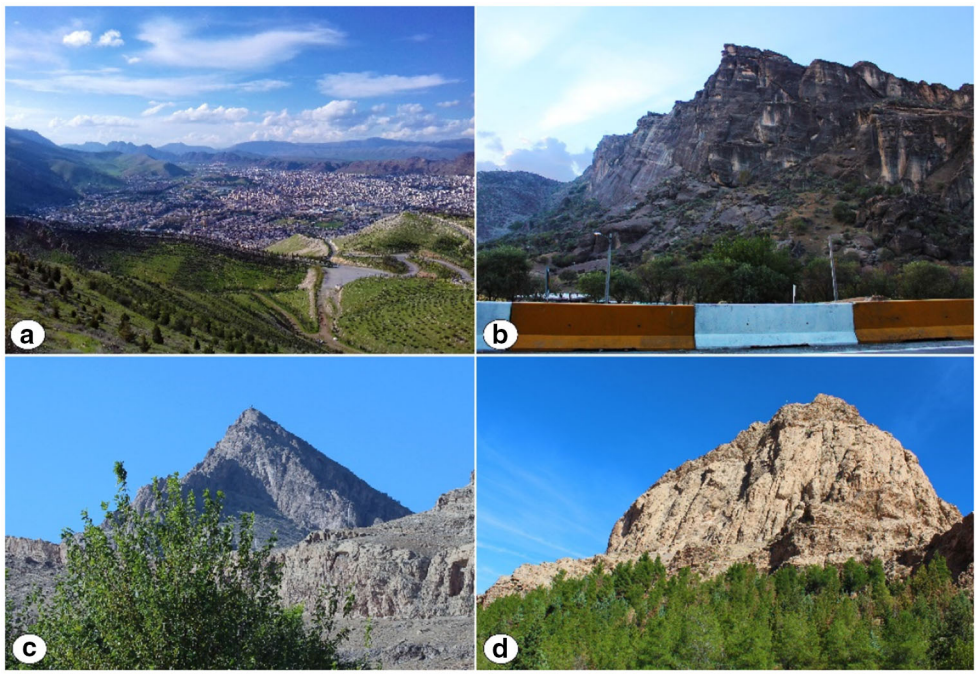


**Fig. 7** Landscape and some geomorphosites in Khorramabad City and its ETJ. **a** Khorramabad City landscape; **b** Maxmalkuh Mountain; **c** Sefidkuh Mountain; **d** Modbe Mountain


**Fig. 8** Some geomorphosites in Khorramabad City. **a** Khorramabad River-Shapuri Bridge; **b** Kargane River (as specific site); **c** Falak-ol-Aflak Hill and Castle; **d** Kiyo Lake


**Fig. 9** Some geomorphosites in Khorramabad City and its ETJ. **a** Tallaei Waterfall; **b** Sangsila Natural Arch; **c** Hoze-e Musa Valley; **d** Park-e Jangali Valley; **e** Shabixun Cluse; **f** Absharan Valley; **g** Gerdab-e Sangi Stone Pond

**Table 8** Results of the scientific value (SV) assessment of urban geomorphosites in Khorramabad (*N*, natural; *A*, anthropogenic; *S*, specific site)

| No. | Geomorphosite | Type | SV | Class | No. | Geomorphosite | Type | SV | Class |
|---|---|---|---|---|---|---|---|---|---|
| 17 | Falak-ol-Aflak Castle Hill | S | 93.75 | Very high | 21 | Hoze-e Musa Valley | S | 58.75 | High |
| 5 | Maxmalkuh Mountain | N and S | 92.5 | Very high | 9 | Tallaei Waterfall | N | 57.5 | High |
| 7 | Kaldar Cave | A | 82.5 | Very high | 1 | Mahibazan Folds | N | 56.25 | High |
| 22 | Modbe Mountain | N and S | 76.25 | Very high | 18 | Golestan Springs | S | 53.75 | High |
| 8 | Absharan Valley | N | 75 | High | 12 | Sarab Shahva Spring | S | 52.5 | High |
| 24 | Khorramabad River-Shapuri Bridge | S | 75 | High | 6 | Robat River | S | 51.25 | High |
| 3 | Shabixun Close | N | 73.75 | High | 29 | Konji Cave | A | 50 | Moderate |
| 23 | Sefidkuh Mountain | N and S | 71.25 | High | 28 | Peleborj Hill | N | 48.75 | Moderate |
| 14 | Qamari Cave | N | 68.75 | High | 4 | Park-e Jangali Valley | N | 47.5 | Moderate |
| 16 | Khorramabad River-Safavi Bridge | S | 68.75 | High | 13 | Kargane River | S | 46.25 | Moderate |
| 10 | Kiyo Lake | A | 67.5 | High | 25 | Gilvaran Cave | N | 46.25 | Moderate |
| 31 | Changaie Karstic Collection | N | 67.5 | High | 26 | Khorramabad River-Goldasht | S | 45 | Moderate |
| 20 | Sangsila Natural Arch | N | 66.25 | High | 32 | Khorramabad River-Cham Anjir | S | 45 | Moderate |
| 11 | Khorramabad Rocky Park | S | 65 | High | 2 | Mahibazan Colored Outcrop | A | 43.75 | Moderate |
| 19 | Khorramabad Stone Encryption | A | 63.75 | High | 30 | Nilufar Pond | A | 43.75 | Moderate |
| 15 | Gerdab-e Sangi Stone Pond | A | 58.75 | High | 27 | Masur Hill | A | 40 | Moderate |

Finally, a comparison of the values of each geomorphosite in the four criteria of scientific, educational, geotourism and degradation risk is shown in Fig. 10. According to results, in three criteria of the scientific, educational and geotourism, most of the geomorphosites have high and very high value for purposes of urban geotourism/geoeducation in Khorramabad City. Also, some of the geomorphosites are of moderate value and none of the geomorphosites studied have got low value. This is due to the non-selection of low value geomorphosites at the inventoried steps, indicating the suitability of the geomorphosite inventory method for selecting high-potential geomorphosites in Khorramabad City. Although urban geomorphosites have high values in terms of the three criteria mentioned above, on the contrary, most urban geomorphosites have a high value of degradation risk. So that only 9 geomorphosites are in better conservation status and the other 23 geomorphosites are in poor condition and require more attention. Therefore, given the high value gained by most of the studied geomorphosites, it is necessary to pay attention to the conservation status of these geomorphosites to preserve their scientific, educational and geotourism values. Also, preserving them for the current generation as well as the next generation and finally sustainable use for purposes of urban geotourism and geoeducation is very important.

## Discussion

One of the reasons why geosites and geomorphosites assessment methods in natural areas are not suitable for geosites and geomorphosites assessment in urban areas is that they do not take into account the characteristics and features of the urban environments. Moreover, urban geodiversity (Kubalíková et al. 2017; Ticar et al. 2017) is not considered in most of these methods. However, the issue of geodiversity is a major issue in urban geotourism and the variety of phenomena (natural and cultural) is very important for attracting tourists to a city.

The assessments of geomorphosites in the present study have been carried out based on Brilha's (2016) modified method. In Brilha's (2016) method, the sum of scores for each criterion is 100 to 400, which is conceptually not widely understood by the general public, but in this study have been calculated in percentage terms to make it more understandable, based on Eqs. 1–4. Also, a classification into four categories of the low, medium, high and very high was considered for easier comparison of scores in all four criteria. In some Brilha method indicators such as safety, population density, economic level and proximity to recreational areas, considering the area of the city proper and extraterritorial jurisdiction, the parameters are defined so that all urban geomorphosites are given the same value. Therefore, in the present study, the parameters of each indicator were modified according to the environmental characteristics of Khorramabad City. In this study, indicators and parameters in the scientific value criterion are essentially emphasizing on urban geomorphology characteristics. In addition, some indicators include urban physical development, urban geomorphology history, cultural value and urban viewpoints that were defined and added to the Brilha method, because the importance of these indices and their parameters has been recognized in recent studies (Del Lama et al. 2015; Chan and Godsey 2016; Reynard et al. 2017; Pica et al. 2017; Habibi et al. 2018; Chylińska and

**Table 9** Results of the educational value (EV) assessment of urban geomorphosites in Khorramabad

| No. | Geomorphosite | EV | Class | No. | Geomorphosite | EV | Class |
|---|---|---|---|---|---|---|---|
| 17 | Falak-ol-Aflak Castle Hill | 92.5 | Very high | 9 | Tallaei Waterfall | 62.5 | High |
| 24 | Khorramabad River-Shapuri Bridge | 88.75 | Very high | 1 | Mahibazan Folds | 60 | High |
| 5 | Maxmalkuh Mountain | 87.5 | Very high | 15 | Gerdab-e Sangi Stone Pond | 60 | High |
| 16 | Khorramabad River-Safavi Bridge | 86.25 | Very high | 12 | Sarab Shahva Spring | 57.5 | High |
| 10 | Kiyo Lake | 85 | Very high | 14 | Qamari Cave | 57.5 | High |
| 22 | Modbe Mountain | 81.25 | Very high | 28 | Peleborj Hill | 57.5 | High |
| 23 | Sefidkuh Mountain | 81.25 | Very high | 29 | Konji Cave | 57.5 | High |
| 11 | Khorramabad Rocky Park | 76.26 | Very high | 4 | Park-e Jangali Valley | 56.25 | High |
| 3 | Shabixun Cluse | 76.25 | Very high | 18 | Golestan Springs | 56.25 | High |
| 8 | Absharan Valley | 72.5 | High | 27 | Masur Hill | 56.25 | High |
| 13 | Kargane River | 72.5 | High | 2 | Mahibazan Colored Outcrop | 52.5 | High |
| 26 | Khorramabad River-Goldasht | 71.25 | High | 32 | Khorramabad River-Cham Anjir | 52.5 | High |
| 19 | Khorramabad Stone Encryption | 70 | High | 30 | Nilufar Pond | 50 | Moderate |
| 7 | Kaldar Cave | 66.25 | High | 21 | Hoze-e Musa Valley | 48.75 | Moderate |
| 31 | Changaie Karstic Collection | 65 | High | 25 | Gilvaran Cave | 47.5 | Moderate |
| 20 | Sangsila Natural Arch | 63.75 | High | 6 | Robat River | 46.25 | Moderate |

Kołodziejczyk 2018; Melelli 2019). It is worth noting that Brilha's (2016) method is generally used to the assessment of geosites and it is normal that some parameters are not suitable for a specific purpose and specific area such as the urban environment. The Brilha (2016) method was modified for this study and can be applied to similar areas. Pica et al. (2017) proposed the first method for evaluation of urban geomorphological heritage which they emphasized on geohistorical aspects, landscape analysis and geotourism. These aspects were considered in the present study to modify the Brilha method. Also, the criteria and indicators presented in their approach are more limited than the present study, in terms of different aspects of geomorphosite evaluation.

The geomorphological heritage of the Khorramabad City proper and its extraterritorial jurisdiction, due to its values such as scientific, educational and geotourism in the moderate to very high range, has great potential to become a centre of urban geotourism and the development of urban geotourism in

**Table 10** Results of geotourism/recreational value (GV) assessment of urban geomorphosites in Khorramabad

| No. | Geomorphosite | GV | Class | No. | Geomorphosite | GV | Class |
|---|---|---|---|---|---|---|---|
| 17 | Falak-ol-Aflak Castle Hill | 83.75 | Very high | 26 | Khorramabad River-Goldasht | 55 | High |
| 10 | Kiyo Lake | 82.5 | Very high | 28 | Peleborj Hill | 55 | High |
| 16 | Khorramabad River-Safavi Bridge | 77.5 | Very high | 31 | Changaie Karstic Collection | 55 | High |
| 24 | Khorramabad River-Shapuri Bridge | 75 | High | 7 | Kaldar Cave | 52.5 | High |
| 5 | Maxmalkuh Mountain | 73.75 | High | 27 | Masur Hill | 52.5 | High |
| 22 | Modbe Mountain | 72.5 | High | 9 | Tallaei Waterfall | 51.25 | High |
| 23 | Sefidkuh Mountain | 72.5 | High | 13 | Kargane River | 51.25 | High |
| 11 | Khorramabad Rocky Park | 71.25 | High | 1 | Mahibazan Folds | 50 | Moderate |
| 8 | Absharan Valley | 70 | High | 14 | Qamari Cave | 50 | Moderate |
| 19 | Khorramabad Stone Encryption | 65 | High | 29 | Konji Cave | 48.75 | Moderate |
| 20 | Sangsila Natural Arch | 61.25 | High | 6 | Robat River | 47.5 | Moderate |
| 3 | Shabixun Close | 60 | High | 30 | Nilufar Pond | 47.5 | Moderate |
| 15 | Gerdab-e Sangi Stone Pond | 58.75 | High | 32 | Khorramabad River-Cham Anjir | 42.5 | Moderate |
| 12 | Sarab Shahva Spring | 56.25 | High | 21 | Hoze-e Musa Valley | 40 | Moderate |
| 18 | Golestan Springs | 56.25 | High | 2 | Mahibazan Colored Outcrop | 38.75 | Moderate |
| 4 | Park-e Jangali Valley | 55 | High | 25 | Gilvaran Cave | 33.75 | Moderate |

**Table 11** Results of degradation risk value (DRV) assessment of urban geomorphosites in Khorramabad

| No. | Geomorphosite | DRV | Class | No. | Geomorphosite | DRV | Class |
|---|---|---|---|---|---|---|---|
| 8 | Absharan Valley | 88.75 | Very high | 27 | Masur Hill | 65 | High |
| 5 | Maxmalkuh Mountain | 87.5 | Very high | 1 | Mahibazan Folds | 62.5 | High |
| 28 | Peleborj Hill | 78.75 | Very high | 12 | Sarab Shahva Spring | 58.75 | High |
| 13 | Kargane River | 78.75 | Very high | 3 | Shabixun Close | 56.25 | High |
| 22 | Modbe Mountain | 77.5 | Very high | 11 | Khorramabad Rocky Park | 56.25 | High |
| 24 | Khorramabad River-Shapuri Bridge | 77.5 | Very high | 17 | Falak-ol-Aflak Castle Hill | 51.25 | High |
| 2 | Mahibazan Colored Outcrop | 76.25 | Very high | 31 | Changaie Karstic Collection | 51.25 | High |
| 26 | Khorramabad River-Goldasht | 71.25 | High | 21 | Hoze-e Musa Valley | 50 | Moderate |
| 6 | Robat River | 70 | High | 9 | Tallaei Waterfall | 50 | Moderate |
| 30 | Nilufar Pond | 70 | High | 29 | Konji Cave | 46.25 | Moderate |
| 20 | Sangsila Natural Arch | 68.75 | High | 19 | Khorramabad Stone Encryption | 42.5 | Moderate |
| 23 | Sefidkuh Mountain | 66.25 | High | 14 | Qamari Cave | 41.25 | Moderate |
| 4 | Park-e Jangali Valley | 66.25 | High | 18 | Golestan Springs | 40 | Moderate |
| 16 | Khorramabad River-Safavi Bridge | 65 | High | 7 | Kaldar Cave | 38.75 | Moderate |
| 15 | Gerdab-e Sangi Stone Pond | 65 | High | 10 | Kiyo Lake | 30 | Moderate |
| 32 | Khorramabad River-Cham Anjir | 65 | High | 25 | Gilvaran Cave | 28.75 | Moderate |

regional scale. In line with the results of this study, previous studies have shown that some cities have a high potential for the development of urban geotourism. Four of the world's examples are Sao Paulo in Brazil (see Del Lama et al. 2015),

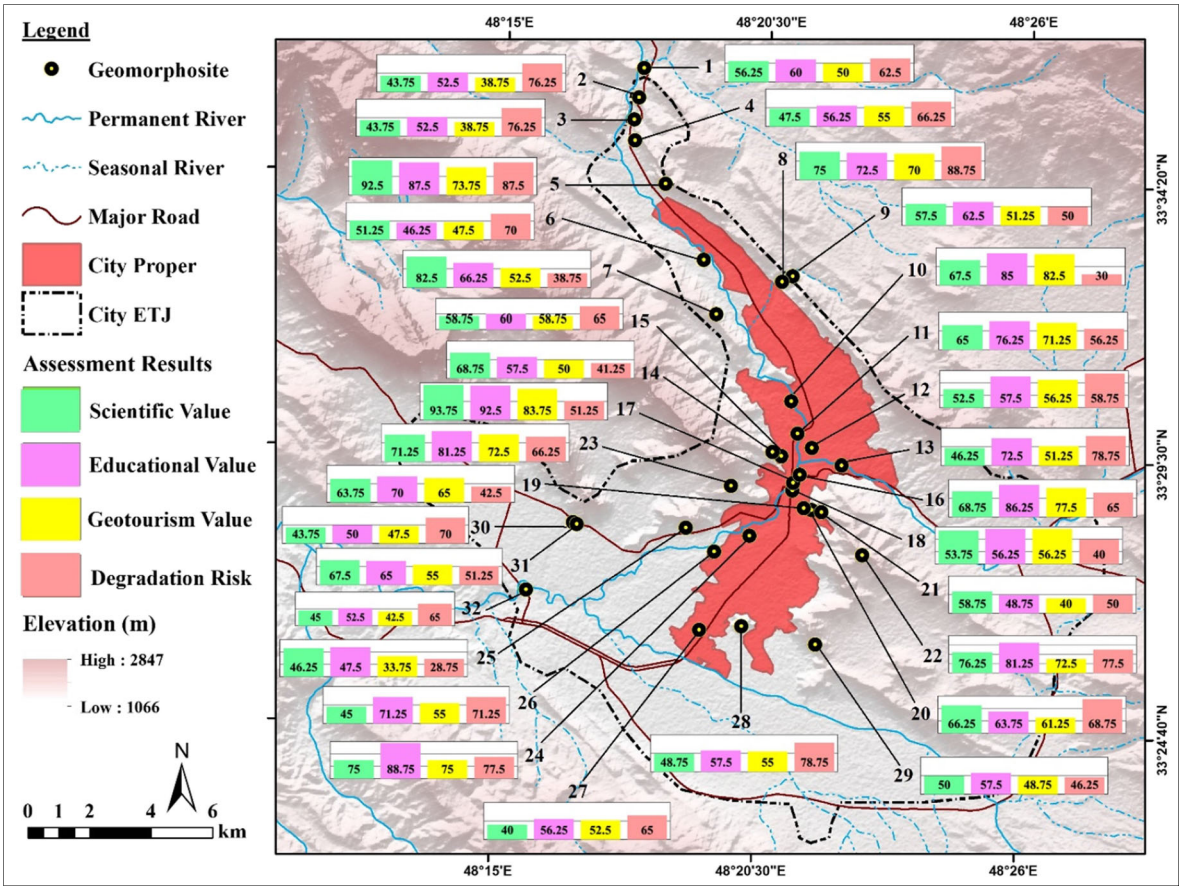


**Fig. 10** A comparison of the values of each geomorphosite in the four criteria of scientific, educational, geotourism and degradation risk (see Table 7 for names of geomorphosites based on the numbers 1 to 32)

Pruszków in Poland (see Górska-Zabielskamaria and Zabielski 2017), Rome in Italy (see Pica et al. 2017) and Cairo in Egypt (see AbdelMaksoud et al. 2018).

## Conclusion

Within such an area as the Khorramabad City proper and its extraterritorial jurisdiction, the presence of diverse geomorphosites of high scientific, educational and geotourism values indicates the high potential of this city for urban geotourism development. Based on the linear distribution pattern of these geomorphosites, suitable geotourism routes with the shortest visit time can be provided to tourists. Besides, the location of geomorphological heritage in urban areas and near educational centres (including secondary schools and universities) helps teachers and students of geoscience to gain the best educational benefit in the least amount of time and cost. For example, the Shabixun Cluse and the river flowing in it, erosional forms, caves, Maxmalkuh Mountain and its seasonal waterfalls alongside ancient sites have created a specific urban geodiversity and geomorphodiversity in only a small area of the north of the city that are aesthetically very attractive and very suitable for training from an educational viewpoint. Such geotouristic complexes are abundant in the study city. Given the geomorphological heritage of Khorramabad City, along with other geodiversity and anthropogenic elements such as local rocks used in the body of historical monuments, city streets and sidewalks, the urban geotourism of Khorramabad will certainly be greatly enhanced.

In this study, for urban geomorphosite assessment, two important aspects are emphasized for modifying the Brilha (2016) method: first, the modification of the parameters is appropriate to the characteristics of urban environment and achieve a suitable assessment of urban geomorphosites and, second, enhancing the indicators and parameters needed to the assessment of urban geomorphosites. The advantage of this is to quantify the different natural and cultural values of geomorphosites in urban environments by analysing multiple factors through field observations and measurements, analysing scientific, educational and geotourism values for use by urban tourists, urban people, scientific centres etc. In addition, the results of the degradation risk assessment of geomorphosites are extremely important for management and conservation measures in an urban area.

In the meantime, what is important is that given the geomorphosites in the urban area and the growth/expansion of the city in the coming years, and consequently the devastating impacts on these geomorphosites, management and conservation actions are required to be taken to conserve geomorphosites values, especially the scientific, educational and geotourism values of vulnerable geomorphosites in order to prevent any further damage to them. As the results showed, some geomorphosites have a high degradation risk; hence, for geotourism development in Khorramabad City without damaging the geomorphological heritage and unknown geoheritage, we propose the management and conservation action plan developed for conserving geomorphosites. To achieve this purpose, creating and developing a legal conservation status, for example, recognizing the geological/geomorphological heritage as a new urban land use (urban use) by the municipality of Khorramabad, or conservation as heritage within an urban area same as cultural heritage in cities, are the practical and actual mechanism for solving conservation issues of geomorphosite under the influence of urban development and human activity.

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