



# Inventory, Evaluation, and Mapping of the Geological and Geomorphological Sites of the Tazekka National Park (Middle Eastern Atlas, Morocco)

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## Abstract

The Tazekka National Park (TNP) harbors significant geological, geomorphological, ecological, and cultural richness that remains undervalued. This study aims to assess, prioritize, and map the geosites within the TNP in the Middle Eastern Atlas, Morocco. The evaluation method used in this work is based on intrinsic values (scientific, ecological, aesthetic, and cultural) and characteristics of use and management, integrating the social dimension. The social dimension was characterized through a set of questionnaires (630 interviews) for various local actors in the park. The evaluation of the studied sites showed that the majority have high scientific value, with 14 geosites exceeding the average scientific value of 0.72. Ecologically, the inclusion of the study area in the National Parks and Protected Areas Act has increased the ecological value of the geosites, with 20 allowing high to very high biodiversity development. Additionally, 28 sites have very high aesthetic value. The social dimension (cultural value) reveals that the 31 geosites evaluated are of very significant cultural value, rooted in the traditions, identity, and legends of the local population and the characteristics of the territory. TNP boasts exceptional geological and geomorphological features, positioning it as a highly sought-after tourist destination. This involves safeguarding geomorphological sites, raising awareness among local stakeholders, and maximizing these assets to drive regional development while conserving this natural heritage. These findings offer crucial insights to aid policymakers in their endeavors to protect and enhance geomorphosites.

**Keywords** Geosites · Geoheritage · Social dimension · Tazekka national park · Middle Eastern North Atlas · Morocco

## Introduction

On a global scale, and especially at the level of developed countries, the growing interest in geodiversity emerged in the early 2000s. This attention to landscapes and geological heritage should be viewed alongside the significant

transformations occurring in developing nations. These countries are striving to harness their entire natural and cultural resources for tourism, aiming to invigorate their economy, society, and territorial growth. For this reason, legislative and scientific initiatives have shown a growing interest in geological and/or geomorphological heritage (Brilha 2018; Crofts and Gordon 2015; Crofts et al. 2020). In Morocco, several scientific works have extensively explored the geological heritage (Beraaouz 2011; Bouzekraoui et al. 2018; Charroud 2011; El Hadi et al. 2011; Errami et al. 2015; Hili 2021; Mehdioui et al. 2020; Ait Omar et al. 2022; Rais et al. 2021; Saddiqi et al. 2015). The majority of these works have focused on inventory, assessment, and mapping of geoheritage, with less emphasis placed on strategies for its preservation, using the University of Lausanne methodology, for example, Louz et al. (2022), Ait Omar et al. (2022), and Hili (2021).

However, the geological and/or geomorphological forms and processes are diverse, holding significant heritage value,

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yet they remain unknown and ignored by management and territorial development actors, as well as the general public. In response, scientists have conducted various research projects to increase awareness among local stakeholders for the preservation of these geoheritages. While the ecological heritage (biodiversity) is well-protected through measures such as protected areas, nature reserves, Sites of Biological and Ecological Interest (SIBE), biological reserves, and national parks, the geological and geomorphological heritage (geodiversity) is absent in environmental legislation. It is indirectly protected under its location within a protected area or a national park (Hili 2021). It's crucial to note that the field of protecting and enhancing geo-morphological heritage is significantly neglected in Morocco (Louz et al. 2022). Therefore, substantial efforts are still required in terms of inventory, evaluation, protection, and enhancement in this domain.

The Tazekka National Park (TNP) holds significant geological, geomorphological, ecological, and cultural potential that, unfortunately, remains undervalued. This natural and cultural geoheritage can play a crucial role in environmental education, serving as an open-air laboratory for young researchers to comprehend various processes in the regional morphogenesis of the North Eastern Middle Atlas (karstic, fluvial, gravity processes, etc.). The analysis of the questionnaire revealed a low level of knowledge about geological and/or geomorphological forms and processes (such as fossils, ruiniform landscapes, etc.) and limited awareness of the concept of geosites (Strasser et al. 1995; Grandgirard 1997a, b; Reynard 2004; Pralong 2006), with only 5 out of 630 respondents familiar with this notion. This work aims to make this geoheritage known by inventorying, evaluating, and mapping the 31 geosites within Tazekka National Park.

Furthermore, the article seeks to provide insights into the current status of these sites, with the overarching goal of raising public awareness about the imperative need to preserve and nurture the park's resources. Through this research, we aim to document, evaluate, prioritize, and map the geosites of Tazekka National Park. Our objective is to disseminate information on the current situation of geosites, encouraging public participation in the protection and enhancement of the park. In doing so, we aspire to contribute to the popularization of this theme, highlighting concepts like geo-morpho-logical heritage, and geosites, to increase awareness and improve landscape culture. Moreover, we aim to i) minimize the harmful impacts of tourism on the geosites (preventing site degradation) of the park, and ii) create a document to aid in managing, developing, and enhancing the geoheritages of the Tazekka National Park (TNP).

## Materials and Methods

### Study Area

The Tazekka National Park, situated in the northeastern part of the Middle Atlas, is located approximately 30 km southwest of the province of Taza (Fig. 1), covering an area of 138 km<sup>2</sup>. The main geological and geomorphological forms in this region result from a combination of various natural factors, including climate, tectonics, lithology, topography, and vegetation cover.

Geologically, Tazekka National Park is divided into three distinct geological parts (Fig. 2). The primary Tazekka massif covers the western part of the park, featuring metamorphosed schistose formations from the Paleozoic era. The middle Atlas tabular rises of the secondary (North of Bab Boudir) consist of limestone formations from the Middle Lias, while the folded Middle Atlas of the secondary (covering the eastern part of the park) is characterized by hard and permeable formations of lower Lias limestone and dolomitic limestone (Robillard 1978; Hoepffner 1994; Sabaoui et al. 2009; Taous et al. 2009; Hili and El Khalki 2017; Hili 2021).

Structurally, the park is known for its fractured structure marked by numerous faults, with the most notable being the North Middle Atlas Accident (Ek and Mathieu 1964; Robillard 1978). The presence of Permo-Triassic clay formations played a significant role in the evolution of hydrogeology and fluvial-karstic processes in the study area.

In the two Liassic faulted and karstified sections, the interplay of factors, including climate, slope, and others, facilitated the development of karstification in limestone outcrops. This process affected dolomites, dolomitic limestones, and limestone dolomites, leading to the formation of typical karst landforms.

### Methodology

After studying more than 10 geomorphosite assessment methods (including those by Cendrero 1996; Grandgirard 1997a, b; Serrano and González-Trueba 2005; Pralong 2006; Pereira et al. 2007; Reynard et al. 2007; Zouros 2007; Coratza et al. 2012; Kubalíková and Kirchner 2013; Maran Stevanović 2015; Reynard et al. 2016, Mucivuna et al. 2019), and considering the characteristics of TNP as a biodiversity and biotope protection area, it can be concluded that the method developed by Reynard et al. (2016) is the most suitable for our use. The decision to apply this method in our context (TNP) and to propose our pre-selection sheet is justified by the following reasons:

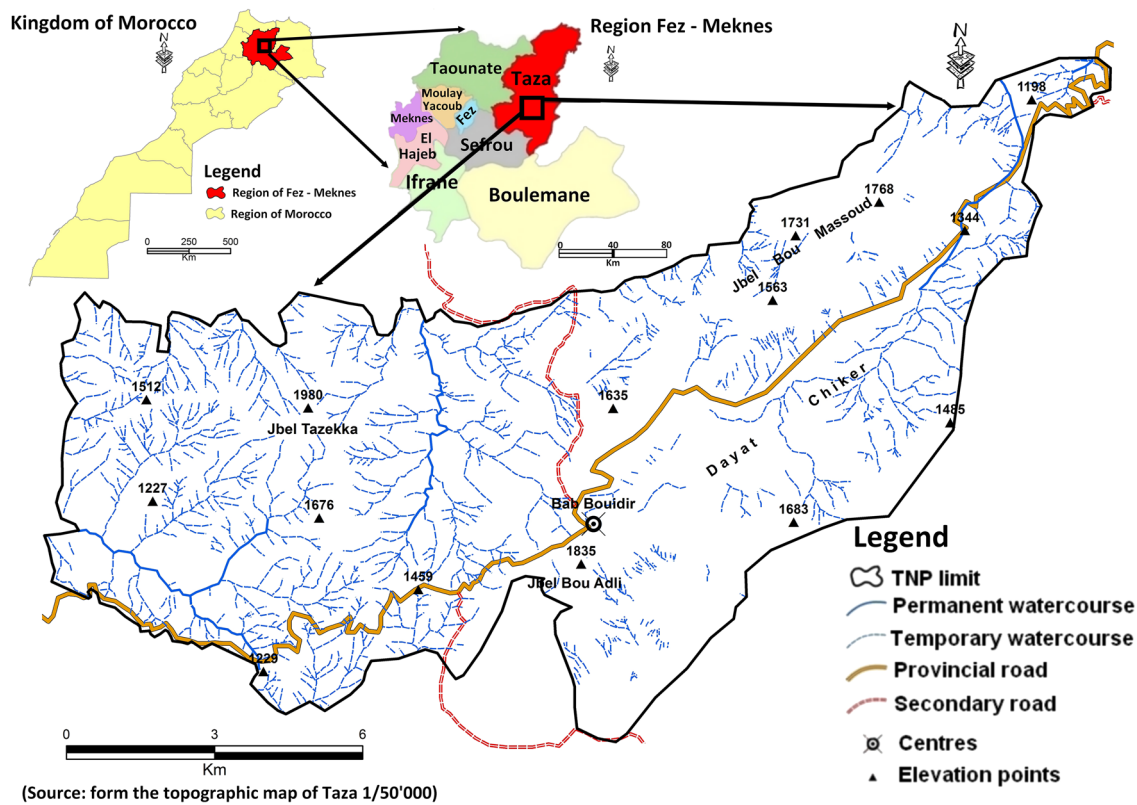


Fig. 1 Geographic location of Tazekka National Park

- Most methods provide geosite evaluations through scores but lack cartographic representations, which are essential for our needs.
- Our territory's geosites require thorough evaluation and cartography to showcase the geological and geomorphological potential of the TNP.
- The inclusion of additional values (aesthetic and ecological) involves assigning pictograms for weighting.
- Creation of summary maps, including values, conditions of use, and damage and protection status. These maps should present all necessary geosite information (scientific value, additional values, and use and management characteristics) in a spatialized and easily readable format, suitable for a wide audience, managers, and specialists alike.
- Given that the evaluation of the cultural value in the method of Reynard et al. (2016) is descriptive, expressed only by a sentence without a score or pictogram assignment, we attempted to assess this value based on the social dimension.

To achieve this, we partially adopted the method of Reynard et al. (2016) (Fig. 3), incorporating the social dimension of geosites. This includes aspects related to the perception of geomorphological properties by the local population,

visitors, and various local actors such as park managers, elected officials, tourism managers, lodgers, and associations (Fig. 4).

### Evaluation

The scientific value assessment of geosites was conducted based on four criteria by Grandgirard (1997a, b): integrity, representativeness, rarity, and paleogeographic interest. Each criterion received an evaluation and a score ranging from 0 to 1, rounded to a quarter point (Reynard et al. 2007). The method proposes mapping this value with scores ranging from 0 to 100, where 100 is equivalent to a score of 1 (for instance, a score of 0.83 translates to 83 on the map and in the graphs) (Reynard et al. 2016).

A distinction between this method and other Reynard methods lies in its approach to assessing additional values (ecological, aesthetic, and cultural value) purely qualitatively. In other words, it provides an estimate without assigning scores or applying weighting. The method employs simple and easily interpretable pictograms (Fig. 3) instead of numerical scores, facilitating the clear visualization of all evaluation results on the cards.

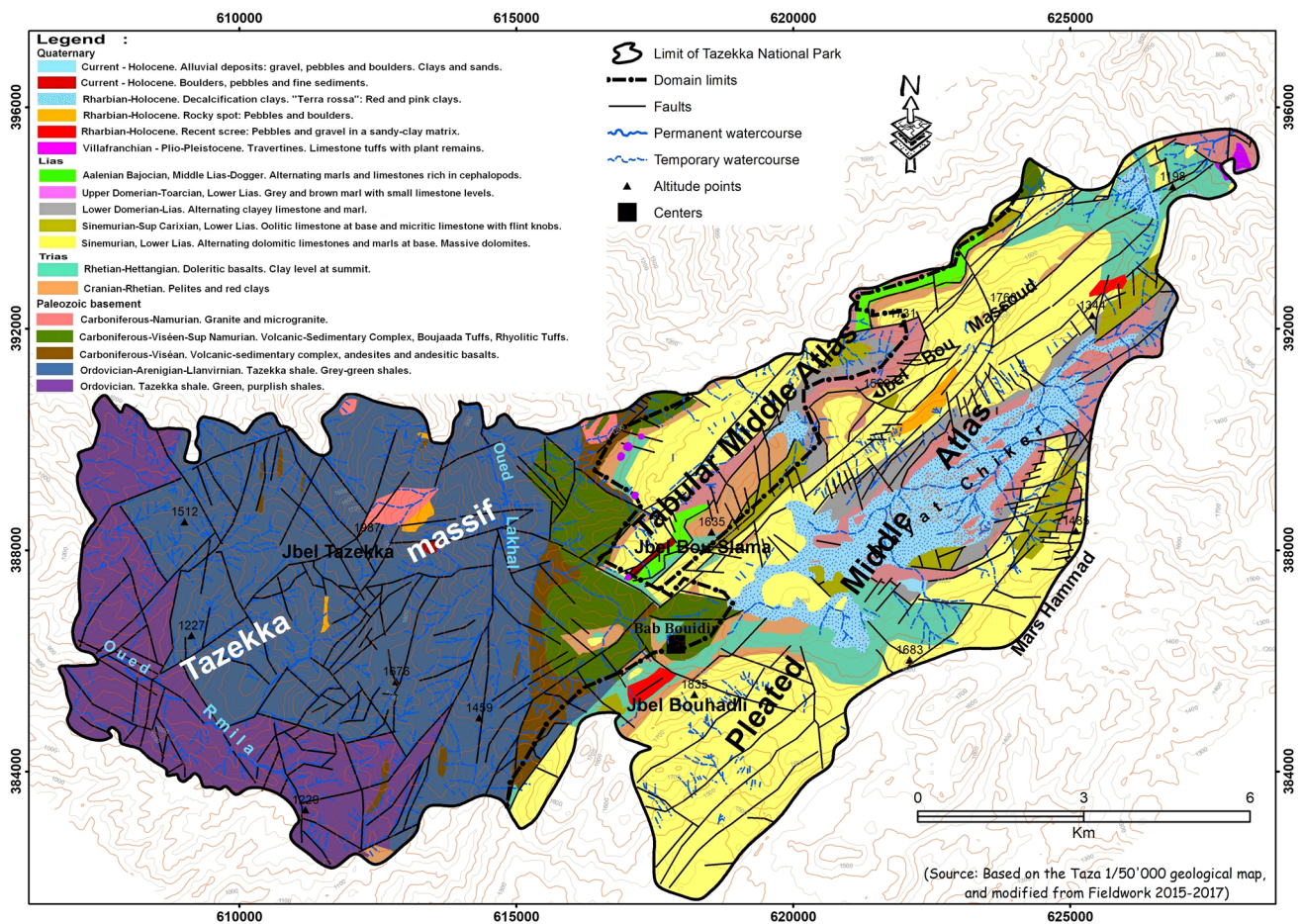


Fig. 2 Geology of Tazekka National Park

For the ecological value of TNP geosites, biodiversity holds a special significance, given the close connection between biotic and abiotic components. According to Reynard et al. (2016), a geomorphosite with significant ecological value is represented by a pictogram featuring a small flower (Fig. 3).

Similar to ecological value, the assessment of aesthetic value is qualitative. Since aesthetic perception is inherently subjective, this criterion evaluates the role of the geomorphosite with the surrounding landscape based on criteria such as viewpoints, contrast, and spatial structuring. According to the method, a geomorphosite with high aesthetic value is assigned a pictogram with a landscape (Fig. 3).

In addition to the scientific and aesthetic values of geosites, cultural value plays a crucial role in enhancing the quality of certain sites. This value is associated with traditions, historical significance, colonial legacies, local beliefs, and habits of the population (e.g., "Moussem – Llama," an annual village gathering).

To incorporate the social dimension and understand the perspectives of various stakeholders in the Tazekka National Park, we conducted a questionnaire involving 630 participants, comprising 166 visitors, 445 local residents (from 8

villages), 4 tourism managers, 6 elected officials, 6 associations, and 3 lodge managers (Fig. 4). For analysis, we utilized the Sphinx software to quantify the repetitiveness of each geomorphosite concerning all the participants. To gauge the perception of the local population, we selected 8 villages, interviewing all individuals (567 men and 63 women). Notably, 115 women declined to answer due to a local tradition that discourages women from conversing with foreigners.

To ensure the success of our approach and diversify opinions and perspectives, we made efforts during the interview phases to engage with different age groups of both visitors and the local population. Our objective is to identify and characterize the social dimension of geosites. Additionally, this approach serves to define the needs and expectations of various stakeholders within the territory of the Tazekka National Park.

To assess the social dimension's value, we employed a numerical scale ranging from 0 to 1 (Table 1). For the cartographic representation of this social value, we selected a cultural symbol from the ancient city of Taza (medina): the chandelier of the great mosque. The size of this pictogram is proportional to the score value, which, in turn, reflects

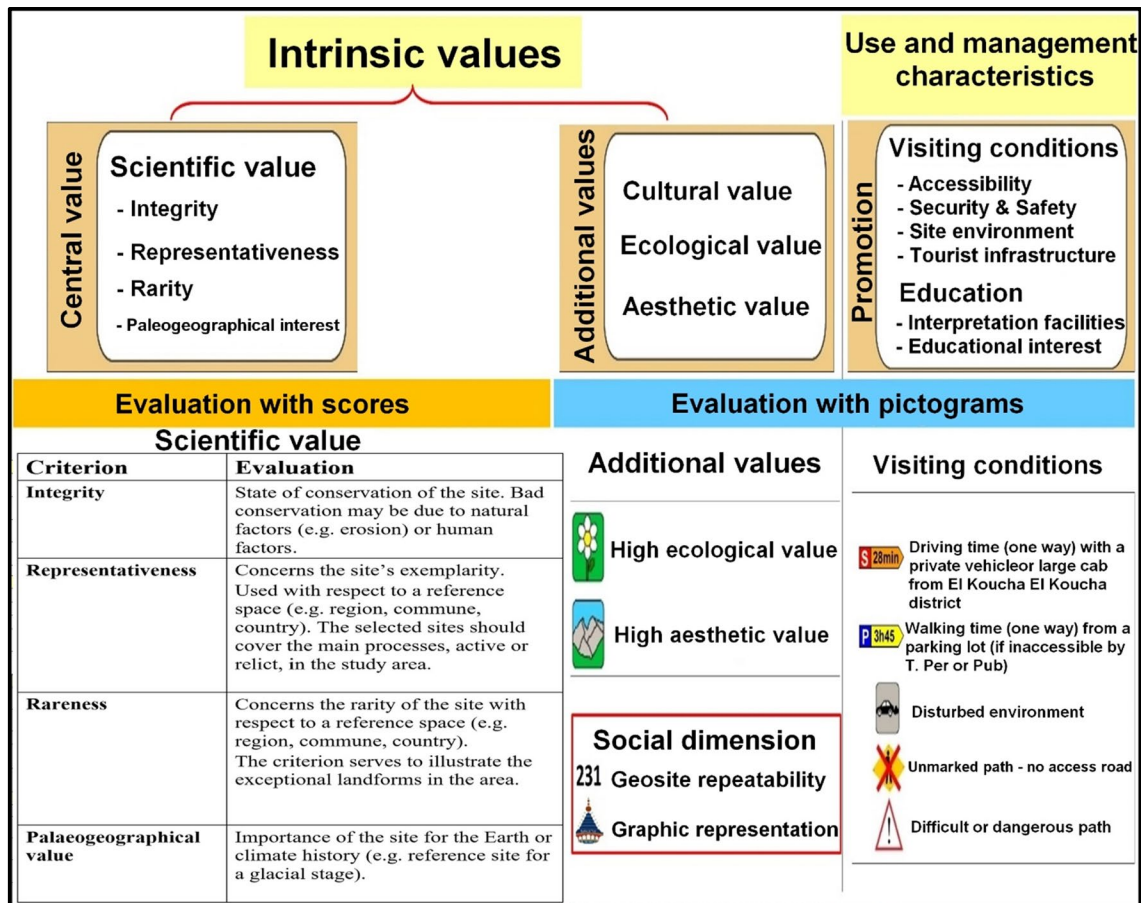
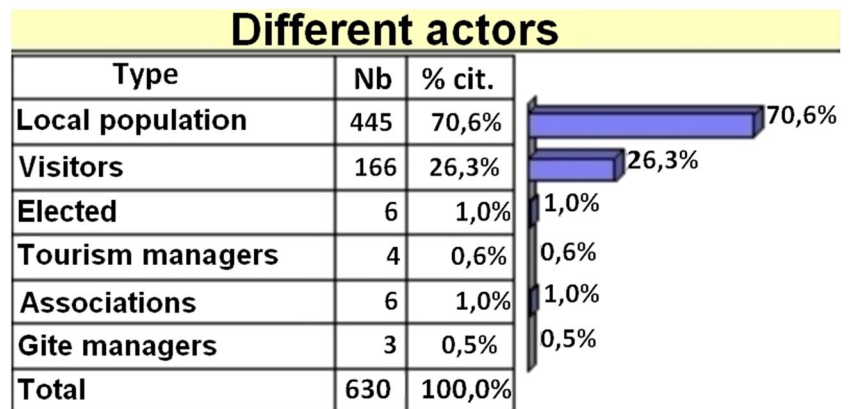


Fig. 3 University of Lausanne geomorphosite evaluation method (modified from Bussard 2014; Reynard et al. 2016)

Fig. 4 Different local actors







how frequently each geosite was mentioned among all the interviewees (630 people).

The assessment of the scientific value (Grandgirard 1997a, b; Coratza and Giusti 2005) remains numerical and central, involving the assignment of scores. In contrast, the assessment of additional values and visitation conditions (often absent in the majority of methods) has become qualitative, represented by easily interpretable pictograms.

### Results

The intrinsic value evaluation of TNP geosites involves both quantitative assessments, using scores for scientific value, and qualitative information represented by pictograms for additional values, especially ecological and aesthetic values (Reynard et al. 2016), along with cultural values

**Table 1** scores, repetitiveness, and cartographic representation of the social dimension

Scores	Geosite repetitiveness	Degree of knowledge of the geosite	Mapping representation
0	The site is not mentioned	The site is unknown	-----
0.25	The site repeats from 1 to 99 times	The site is little-known	
0.5	The site repeats itself 100 to 199 times	The site is moderately known	
0.75	The site repeats 200 to 299 times	The site is well-known	
1	The site repeats itself more than 300 times	The site is very well-known	

assessed through the social dimension. The majority of the inventoried forms result from various processes, including karstic, structural, fluvial, gravitational, and anthropogenic influences.

### Inventory of Geosites

When it comes to selecting geosites, various methods are available (Coratza and Giusti 2005; Reynard 2009; Brilha 2016, 2018). After identifying the different geosites in the park (a total of 55), we opted to propose our pre-selection method tailored to our needs and the challenges encountered during field visits (Table 2). To achieve this, we conducted a pre-assessment using a criteria sheet we developed (Table 2). The creation of this sheet was based on the significance of certain criteria (scientific value, rarity, aesthetics) and accessibility considerations, the state of protection and conservation of geosites, as well as the challenges encountered during field verifications.

In the transition from 55 to 31 geosites, following the preselection, we refined our selection based on i) the scientific interest, rarity, and beauty of the sites (Hili 2021), and ii) the accessibility of the sites, their state of preservation, and their popularity. Considering these criteria and the specific characteristics of each geomorphosite, we finalized a selection of 31 geosites (highlighted in blue in Table 2) for evaluation (Fig. 5). Notably, among these 31 geosites, 20 are cited and recognized by various stakeholders.

To accurately categorize certain geosites, we pursued two strategies: i) identifying the dominant process, exemplified by the division of the complex site of Qelaa into two parts – at the cliff of El Qelaa (TNPSr035) and the karstic complex of El Qelaa (TNPKar036), and ii) grouping multiple geosites (such as sinkholes, springs, ponors, ruiniforms, caves, gorges, etc.) within a complex morphogenic

system. Examples of this include the karstic complex of Sidi Majbar, the karstic complex of Bab Boudir, the Dayat Chiker complex, and the Tighigha karst complex. These complexes encompass various geotopes, including springs, caves, sinkholes, and gorges.

In addition to these geosites, we identified and added nine new ones: the Ain Bechar sinkhole (TNPKar017), the old lead mine (TNPAnt020), the Bab Boudir anticline (TNPSr023), Jbel Bou Massoud (TNPSr026), the Dhar Feurn waterfalls (TNPKar028), the volcano-sedimentary complex (TNPSr029), the scree of El Qelaa (TNPGr038), and the fossilized lapie fields of Jbel Bou Massoud (TNPKar039) and Tighigha (TNPKar043).

The classification of geosites depends on the complexity of the geomorphological sites. Sites can be grouped according to a dominant process, forming complex morphogenic systems, or conserved individually according to the specific processes of each geosite. For example, the Dayat Chiker site represents a complex system, while the El Qelaa site includes different geosites, such as a cliff, a waterfall, and a spring, each resulting from distinct geomorphological processes.

### Evaluation of the Scientific Value

The results of the scientific value assessment showed that the highest scientific value of TNP geosites is around 0.94. It was obtained by seven geosites: four karst sites (Dayat Chiker chasm (TNPKar012), Friouato chasm (TNPKar015) and the fossilized lapie field of Jbel Bou Massoud (TNPKar039) and Tighigha (TNPKar043)), a structural site -karstic (polje of Dayat Chiker-TNPSr-Kar013) and the three structural sites, the anticline of Jbel Bou Massoud (TNPSr026), the volcano-sedimentary complex (TNPSr029) and the Paleozoic massif of Tazekka (TNPSr033). On the other hand, the lowest scientific value is obtained by the

**Table 2** The criteria proposed in this study and the pre-selection results

Sites	Criteria	Scientific interest	Site rarity	Site aesthetics	Popularity	Conservation state	Accessibility	Total
1. Ras El Ma Waterfalls		5	4	5	4	5	3	26
2. Source El Arca		5	3	1	2	5	5	21
3. Msran Djaj Waterfall		5	3	2	2	5	2	19
4. Resurgence of Ras El Ma		5	5	3	5	5	5	28
5. Source Sidi Majbar		3	2	2	5	3	5	20
6. Sidi Majbar Terraces		5	5	5	3	5	5	28
7. Sidi Majbar Gorge		3	3	3	3	5	3	20
8. Widespread erosion Sidi Majbar		4	2	4	3	3	5	21
9. Holm oak on a lapie		4	5	5	3	5	5	27
10. Lapies of Jbel Bou Massoud		5	3	4	3	5	3	24
11. Ponor Dayat Chiker		5	4	1	5	5	5	25
12. Dayat Chiker Chasm		5	5	5	5	5	1	26
13. Dayat Chiker Polje		5	5	5	5	5	5	30
14. Source Dayat Chiker		2	1	1	2	2	5	15
15. Friouato Chasm		5	5	5	5	5	5	30
16. Habitats under Chiker Escarpment		1	3	4	2	5	5	20
17. Ain Bechar sinkhole 1		3	1	2	1	5	5	17
18. Ain Bechar sinkhole 2		3	1	3	1	5	5	18
19. Bou Hayati Cavity		4	3	2	4	4	3	20
20. Old lead mine		3	4	3	3	3	5	21
21. Jbel Bou Slama Cave		5	3	3	3	3	3	20
22. Bou Slama Fossils		5	3	5	4	1	5	23
23. Bab Boudir Anticline		5	3	3	4	5	5	25
24. North Bou Hayati Fault		5	4	3	2	3	5	22
25. Source Tarselt		5	4	2	3	3	5	22
26. Jbel Bou Massoud Anticline		5	3	3	4	5	4	24
27. Bab Boudir Complex		5	3	4	5	3	5	25
28. Dhar Feurn Waterfalls		5	3	5	2	5	5	25
29. Volcano-sedimentary complex		5	5	3	1	5	5	24
30. Ain Admame Exsurgence		4	4	2	5	5	5	25
31. Beni Senane Terraces		1	3	5	5	4	5	23
32. Source El Qdadah		4	3	3	3	2	5	20
33. Tazekka Massif		5	5	5	5	5	5	30
34. Oued Lakhaj Gorge		5	5	5	5	5	3	28
35. El Qelaa Cliff		4	4	5	3	5	4	25
36. El Qelaa Waterfalls + Source		5	4	5	4	5	5	28
37. Agricultural terraces of El Qelaa		4	2	4	3	5	4	22
38. El Qelaa Landslide		4	3	4	2	4	5	22
39. Jbel Bou Massoud Fossils		5	4	5	1	4	5	24
40. Jbel Bou Massoud Fault		5	2	3	1	5	3	19
41. Es-Sebt Monoliths		5	3	3	2	3	5	21
42. Tighigha Monolith		4	3	4	3	3	5	22
43. Tighigha Fossils		5	4	4	2	4	5	24
44. Tighigha Spring		4	2	1	3	3	5	18
45. Ruiniform landscapes of Tighigha		5	5	5	4	4	5	28
46. Colonial Military Camp		3	5	4	2	1	5	20
47. Emergence of Ain Khebbab		4	3	2	5	3	5	22
48. Bab Boudir scree		4	3	3	2	3	4	19
49. Source Bab Boudir		3	2	2	3	3	5	18
50. Bab Boudir Cave		5	3	3	2	3	2	18
51. El Gennanje Waterfall		4	2	2	3	3	4	18
52. Ponor Timesmate		5	3	2	2	4	5	21
53. Lapies Bab Awmchach		5	3	3	2	3	2	18
54. Bab Awmchach Sinkhole		5	2	3	1	3	2	16
55. Bab Awmchah Cavity		3	2	3	2	3	4	17

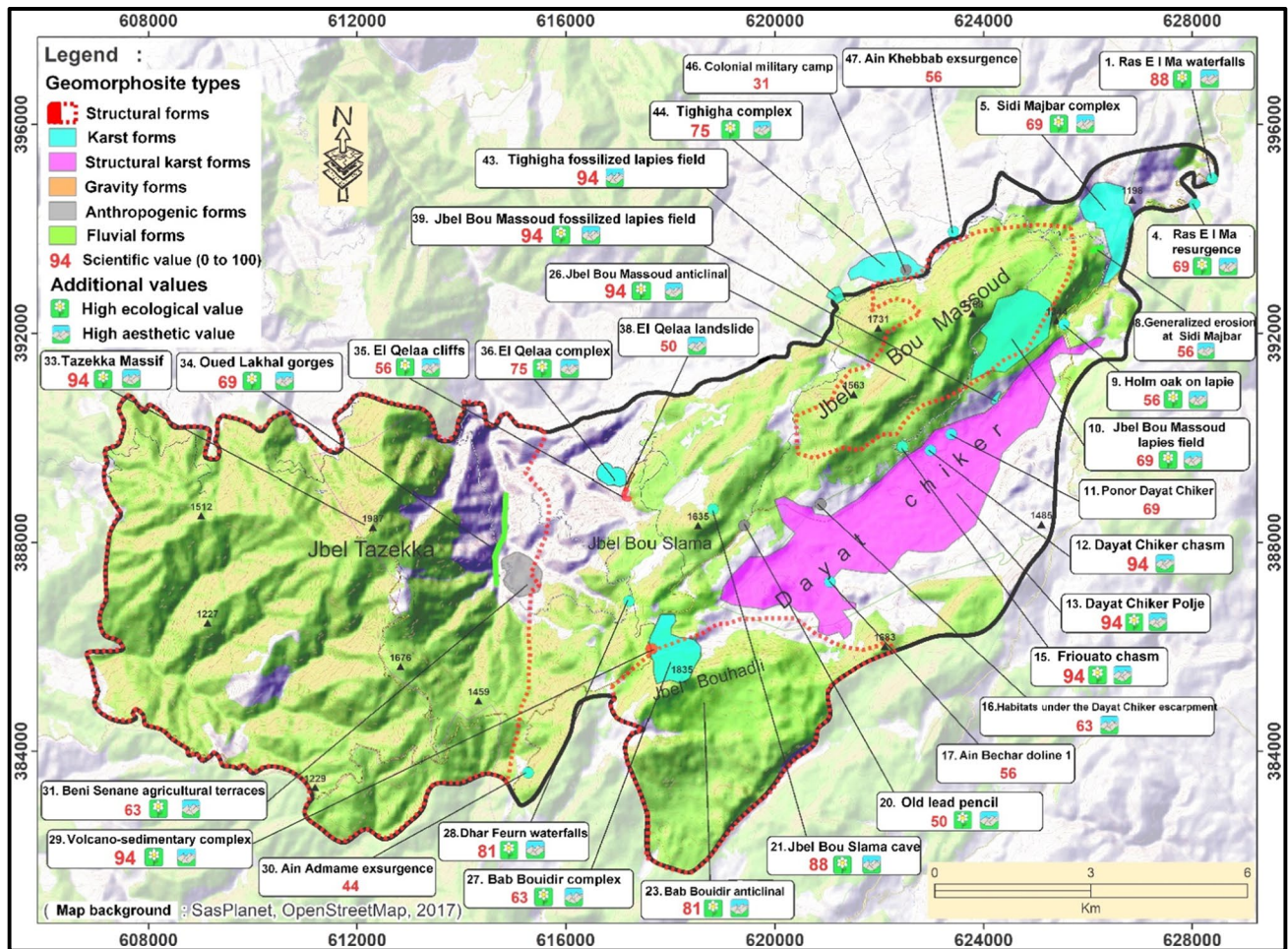


Fig. 5 Evaluation of geosites in Tazekka National Park

military camp (anthropogenic geomorphosite, TNPAnt046), which is around 0.31. The average scientific value is 0.72.

We observed that the morphogenetic processes of geosites directly influence their scientific value. Considering the geological and structural characteristics of the TNP, it became evident that structural, structural-karstic, and karstic forms exhibit a higher average scientific value. This elevated value is primarily attributed to the karstification processes and the structural features that contribute to the formation of the majority of TNP geosites. In contrast, fluvial, gravitational, and anthropic forms are characterized by relatively simpler morphogenetic processes, resulting in a lower average scientific value. This significance associated with the processes is explained by the impact of each criterion of scientific value on its final score (Table 3).

To illustrate the influence of each criterion relative to others and the evaluation results, Table 3 indicates that the criterion of paleogeographic interest is the least evaluated, with a high standard deviation of 0.45 and an average value

of 0.44. This statistical observation suggests that this criterion is more heterogeneous, emphasizing the absence of studies related to paleogeography and the reconstruction of paleoenvironments in the territory of the TNP. In contrast, the other criteria, namely integrity, rarity, and representativeness, exhibit higher representation and evaluation. This justifies the presence of rare geosites in the TNP. Moreover, the high average values of integrity (0.88) and representativeness (0.81) indicate that the majority of geosites are well-preserved and representative of the geomorphology in the study area.

From a paleogeographic perspective, the most representative geosites are located in the northern part of Daya Chiker, particularly the Tighigha complex (TNPKar043) and on the slopes of Jbel Bou Massoud (TNPKar039), featuring well-developed lapie fields (Fig. 6-2). Regarding structural significance, notable geosites include the polje of Daya Chiker (TNPSr-Kar013), the Paleozoic massif of Tazekka (TNPSr033), and the anticline of Jbel Bou Massoud (TNPSr026).



**Table 3** Statistics of scientific value and its four criteria

	Integrity	Representativity	Rarity	Palaeogeographical interest	Scientific value
Mean	0.88	0.81	0.74	0.44	0.72
Deviation	0.20	0.25	0.16	0.45	0.18
Max	1	1	1	1	0.94
Min	0.25	0	0.5	0	0.31

In addition to these, the Friouato chasm (TNPKar015) and the Dayat Chiker sinkhole (TNPKar012) are also of great scientific value. The speleothems in these chasms were utilized in a study on the paleoclimate of North Africa conducted by Wassenburg et al. (2013). These speleothems served as indicators of climate evolution and global environmental changes. Furthermore, in the cave of Jbel Bou Slama (TNPKar021), in addition to speleothems, fossils were discovered in certain areas (Fig. 6-1). The presence of these fossils undoubtedly enhances the paleogeographic interest and scientific value of this geomorphosite.

From a structural perspective, the Paleozoic massif of Tazekka (TNPSr033) stands as the oldest outcrop (1987 m) in the study area. Of primary age, it is formed of metamorphosed Palaeozoic rocks, particularly schists. Its history begins with the intracontinental collision of the Carboniferous (Sabaoui 1998). This formation appears as a high dome resulting from Alpine folding, which uplifted the Hercynian basement and its secondary cover (Taous et al. 2009). It is surrounded by the carbonate formations of the tabular Middle Atlas to the West, North-East, and South, of the Middle Atlas to the East and South-East, and by the Cretaceous formations of the South Rif Strait to the North, with the contact being direct and very visible at the Col du Twahr. This geomorphosite has obtained very high scientific, aesthetic, ecological, and cultural value.

Similarly, the volcano-sedimentary complex (TNPSr029) of the Carboniferous (Morin 1948) presents a structurally significant geomorphosite. It is in the form of a strip outcropping and rests in angular unconformity on the Tazekka shales structured during the pre-Visean upper phase of the

Hercynian orogeny (Robillard 1978; Huon 1985; Hoepffner 1981, 1987; Huon et al. 1987; Huvelin 1992; Sabaoui 1998; Bennouna et al. 2004; Ramirez Merino et al. 2008; Ajamay et al. 2009). Along the northeast edge of the Tazekka massif (TNPStr033), this band (2 to 4 km wide) is very clearly visible near the El Qelaa village (Fig. 7-2) and the Bab Boudir summer center (Fig. 7-1), especially between the part that connects the Bab Boudir campsite (for families) and the Tazekka park hotel (on the right bank of the road from Taza to Bab Boudir), and also near the picnic area of Merjat El Qayd and Hajrat Sbaa. This band is considered to be the part that separates the dolomitic limestones of the folded Middle Atlas and the Triassic (top) and the Tazekka shales (bottom).

### Evaluation of the Ecological Value

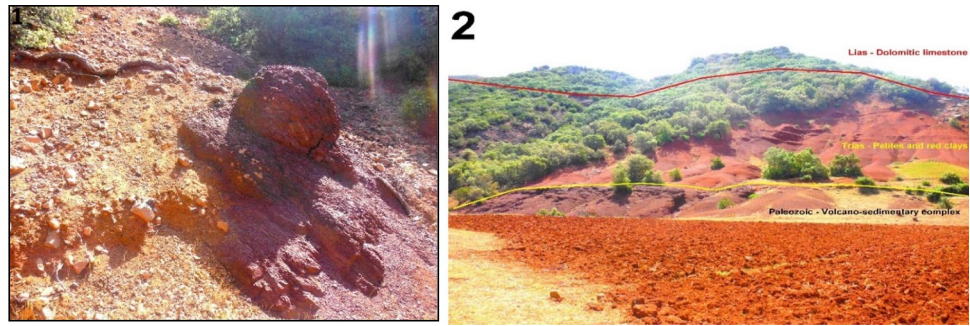
Table 4 shows that 20 geosites (65%) have a high to very high biodiversity value. On the other hand, 5 geosites have no significant influence, and 6 others have an average influence on the ecological and biological life of the park. These results highlight the interaction between the morphogenetic processes of each geomorphosite and biodiversity. The majority of geosites of karstic origin have a direct influence on increasing ecological value.

We can also observe that the geosites (18 sites) of karstic, structural-karstic, and structural origins are the ones with high to very high ecological value (Table 4). In addition to these sites, four karstic geosites have an average value; this is particularly the case for the Dayat Chiker sinkhole (TNPKar012), the Ain Bechar sinkhole (TNPKar017), the Ain Admame exsurgence (TNPKar030), and the field of

**Fig. 6** Fossils found in the cave of Jbel Bou Slama (1); on Jbel Bou Massoud (2)



**Fig. 7** Volcano-sedimentary complex near the summer center of Bab Boudir (1); near village El Qelaa (2)



**Table 4** Relationship between ecological value and morphogenetic processes

Values Shapes	Very weak	Weak	Medium	High	Very high
Structural-karstic	0	0	0	0	1
Structural	0	0	0	1	4
Karsts	0	2	4	5	7
river	0	1	0	1	0
Anthropogenic	1	0	2	0	1
Gravity	0	1	0	0	0
Total	1	4	6	7	13

fossilized lapies of Tighigha (TNPKar043). The last two karstic geosites with a low ecological value are the ponor of Dayat Chiker (TNPKar011) and the exsurgence of Ain Khebbab (TNPKar047).

On the other hand, among the four geosites of anthropic origin, only the site of the agricultural terraces of Beni Senane (TNPAnt031) has a very high ecological value. It presents an exclusive habitat for rare animal and plant species such as '*Galium Rotundifolium*,' '*Veronica Verna*,' '*Digitalis Mauretanica*,' '*Salix Atrocinerea*,' '*Catalaunica*,' and '*Satureja Vulgaris*' (Belahyane 1990; Fennane and Ibn Tatto 1999; Fougrach et al. 2007).

As for fluvial geosites, the site that also supports the development of biodiversity is the geomorphosite of Oued Lakhhal (TNPFlu034). It is famous for its ecological and biological richness. Given the basin's rugged topography and the regular flow of the Oued, it constitutes the habitat for several plant species, including '*Galium Rotundifolium*,' '*Veronica Verna*,' '*Digitalis Mauretanica*,' '*Salix Atrocinerea*,' '*Catalaunica*,' and '*Satureja Vulgaris*' (Belahyane 1990; Fennane and Ibn Tatto 1999; Fougrach et al. 2007), as well as rare animals (fish, snakes, insects, scorpions, birds, foxes, wild boars, etc., based on field observations from 2014–2020).

Among the geosites with very high ecological value, we highlight the Palaeozoic massif of Tazekka (TNPStr033). This site has played a crucial role in the preservation and



**Fig. 8** Faun compodeidae (Diplura) lived in the cave of Jbel Bou Slama

evolution of the cedar of the Middle Atlas. It forms a remarkable mountain ecosystem that has been under protection for over fifty years, representing the most ecologically significant part of the park. The site serves as a testament to the historical extent of Moroccan cedar forests, both in the Middle Atlas and the Rif. The presence of the Berber deer further enhances the value of this geomorphosite, even though the reserve is not open to the public.

Additionally, at the subterranean level, karstic geosites characterized by underground development, such as the Friouato chasm (TNPKar015), the Dayat Chiker sinkhole (TNPKar012), and the Bou Slama cave (TNPKar021), can provide a conducive environment for the evolution of exceptional underground life. According to the Association of Friouato, these three chasms host unique life forms and serve as the exclusive habitat for some blind insects (Fig. 8).

### Evaluation of the Aesthetic Value

Figure 9 presents the role of the size of surface and underground forms in El Qelaa waterfalls, the Polje of Dayat Chiker, multicolored concretions of the Dayat Chiker sinkhole, and Friouato chasm lakes, respectively. Among the 31 geosites evaluated, 28 have an aesthetic value that varies between average and very high. Certainly, the size

**Fig. 9** Role of the size of the surface and underground forms: El Qelaa waterfalls (1); Polje of Dayat Chiker (2); multicolored concretions of the Dayat Chiker sinkhole (3); Friouato chasm lakes (4)



of the geosites (on the surface or in-depth) is the most influential factor in determining the aesthetic value of the sites. During field observations, we noticed that, in most cases, the greater the geomorphosite's vertical, horizontal, underground extension, or overall size, the higher its aesthetic value.

All forms with different processes (karstic, structural, fluvial, gravitational, and anthropic), have attracted and attract visitors to our study area. As for the dominant structural and karstic forms, limestone lithology, structure, and climate have played an important role in the evolution of different underground and surface karst forms (waterfalls, chasms, caves, ruiniform landscapes, lapies, etc.).

**Evaluation of the Cultural Value**

At the Tazekka National Park, each year in mid-April (one day) and September (three days) the inhabitants of the villages of Ras El Ma, Sidi Majbar, Dayat Chiker, village El Qelaa, and village Beni Senane celebrate a "Llama—Mousssem" (Fig. 10-1), to thank God for the good harvests of this year, and to ask him for the prosperity and protection of the inhabitants of the village and the harvests of the years to come. During the Mousssem-Llama, several neighboring inhabitants (Taza, Tahla, Bab Marzouka, Bab Boudir, Ras El Ma, Admame, etc.), go on a "pilgrimage" once a year to the marabouts of the park territory (Moulay Youssef

**Fig. 10** Llama by Beni Senane, Moulay Youssef (1), Clothes left by women in Takhelowicht (2)



from Beni Senane, Sidi Chiker from Dayat Chiker, etc.). Local people and visitors show the strong religious belief that exists in the park.

During field visits, we met at the Moussem of Ras El Ma, El Qelaa, and Beni Senane several women who suffer from celibacy and infertility, and who come to Beni Senane, El Qelaa, Ras El Ma, Sidi Majbar, and Dayat Chiker. Visits are concentrated mainly at the mausoleum of Moulay Youssef (Beni Senane), Sidi Abdellah (El Qelaa), and Sidi Chiker (Dayat Chiker) to i) express their hopes and wishes, and ii) fulfill their promises to God. They also go to the cave of Takhelowicht to beg God. According to the local people, inside this cave, there is a sacred spring (Fig. 10-2), from which sterile women wash their bodies to free themselves from infertility. After the bath, the women leave something of their clothing (underwear, scarves, ...) hanging on the trees next to this cave (Fig. 10-2).

In the same way, another marabout is in the park, his tomb is located near the top of the Tazekka massif. They are Moulay Abdelkader Jilali, a man from Saudi Arabia; it is one of the best-known marabouts in the park. According to a story told by “El Haj Ali” (inhabitant of the Beni Senane village, aged 78), a very long time ago, a sterile French woman came to visit the marabout of Moulay Abdelkader Jilali to beg God. After this visit, she was able to have children.

Thus in addition to the very high scientific value of the Friouato chasm, this site has a great cultural value linked in particular to the stories and legends told, for this the history of the nomination of the Friouato chasm (TNPKar015) tourism engine of the region, varies between the Amazigh appellation (Fri = chasm and Ouato = wind; chasm of the wind), and the legend told by the local population of the two lovers (Fri = young man and Ito = young woman), who died of grief, the beautiful Ito mourned his beloved every day on the edge of the abyss.

In addition to these traditions, the festival (Moussem) of Bab Boudir, which generally takes place in mid-August or at the end of the same month, has always attracted many visitors of different nationalities, and it is the only Moussem organized on the territory of the park. It presents an amalgam of folklore and competitions (Fantazia,

Ahidousse, race to the top of Bouhadli, etc.). The problem is that the officials put an end to the organization of this Moussem (Fig. 11-2). Indeed, the latter was considered the annual meeting of cultural exchange and traditions of all the tribes of the park, where they also changed their news, and this, consequently, brings economic benefits (economic value) to the population local.

Additionally, there are remnants from the period of French colonization (Fig. 11-1), which hold a significant presence within Tazekka National Park, still visible across the park's landscape. Notably, examples like the Bab Boudir complex (used as a summer center, TNPKar027), the military camp (TNPAnt044), and the former lead mine (TNPAnt020) stand as prominent remnants of this era. These vestiges enable park visitors to piece together the history of how the territory was organized and how resources were exploited. However, these historical remnants are currently at risk, lacking any efforts towards their rehabilitation or restoration.

The village of Sidi Majbar holds a special significance as a cultural-karstic complex (TNPKar005), having been recognized as a national cultural heritage in 1949. This designation is attributed to its diverse features, encompassing caves, gorges, springs, and agricultural terraces, as illustrated in Fig. 12. The geomorphosite's importance is underscored by its notable scientific and aesthetic value. Culturally, the site stands out due to the deliberate arrangement of its landscape elements. The inclusion of the rural habitat, minaret, color contrast, spatial extent, distinct viewpoints, and the thoughtful layout of agricultural terraces contribute to endowing this geomorphosite with cultural significance and a high degree of repetitiveness.

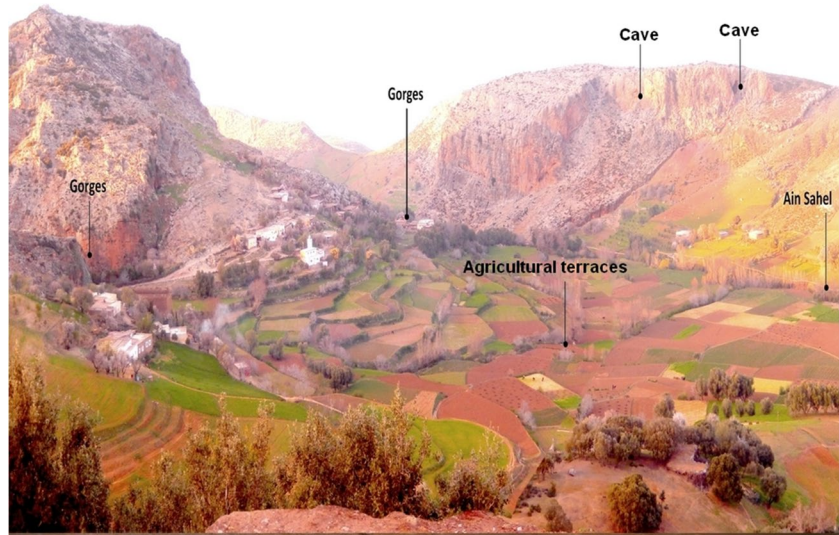
Similarly, the Admame outflow and Sahel source are widely recognized by both the park's residents and the inhabitants of Taza City (Fig. 13). These geosites carry substantial cultural value and a social dimension, attributed to the perceived impact of their waters on digestion.

Therefore, the analysis of cultural value data reveals that the geosites within Tazekka National Park derive significant cultural value from local traditions, the identity of the indigenous population, and the distinctive features of the territory.

**Fig. 11** Bab Boudir summer center (1), Fantazia of the Bab Boudir festival (2)



**Fig. 12** Sidi Majbar geocultural complex



**Fig. 13** Source Sahel in Sidi Majbar (1) and Exsurgence in Ain Admame (2)



This underscores the landscape's importance as a conduit for identity in the agrarian society, which has influenced, generated, and perpetuated these ever-evolving landscapes. Consequently, there is a notable interest in incorporating these geosites into the tourist circuits outlined in this study.

**Evaluation of the Social Dimension**

Unlike the other values (scientific, ecological, and aesthetic value), which are evaluated by the researcher, the social dimension derives its value from the perception of local actors towards the sites (Fig. 14). Indeed, it represents the feelings of belonging, memories, traces, signs, and the repertoire of the past with which they identify, providing a means to recall and understand the history and the relationship with our environment. The juxtaposition of data on the scientific value and social value (Fig. 7) allows us to observe that the 31 selected geosites possess high scientific value and equally high cultural value, with repetitiveness ranging from 100 times to exceeding 300 times among all interviewees.

The analysis of the graph (Fig. 14) reveals a clear relationship between the scientific value and the repetitiveness

of the set of geosites (social dimension). Notably, 17 geosites exhibit high scientific value, including the waterfalls of Ras El Ma (TNPKar001), the resurgence of Ras El Ma (TNPKar004), the geomorphological complex of Sidi Majbar (TNPKar005), the polje of Dayat Chiker (TNPSr-Kar013) and its sites (ponor (TNPKar011) and chasm (TNPKar012)), the chasm of Friouato (TNPKar015), the complex of Bab Boudir (TNPKar027), the exsurgence of Ain Admame (TNPKar030), the agricultural terraces of Beni Senane (TNPAnt031), the massif of Tazekka (TNPSr033), the gorges of the Oued Lakhel (TNPFlu034), the sites of El Qelaa (the karstic complex (TNPKar036) and the cliff (TNPSr035)), the karstic complex of Tighigha (TNPKar044), the colonial military camp (TNPAnt045), and the exsurgence of Ain Khebbab (TNPKar047). These geosites not only possess high cultural and social value but are also well-known among local actors. However, certain geosites, like the Bou Slama cave (TNPKar021), have high scientific value but low repetitiveness (below 100), attributed to the polluted state of the cave and the absence of signage and paths indicating the way to the cave. Additionally, there are geosites with high to very

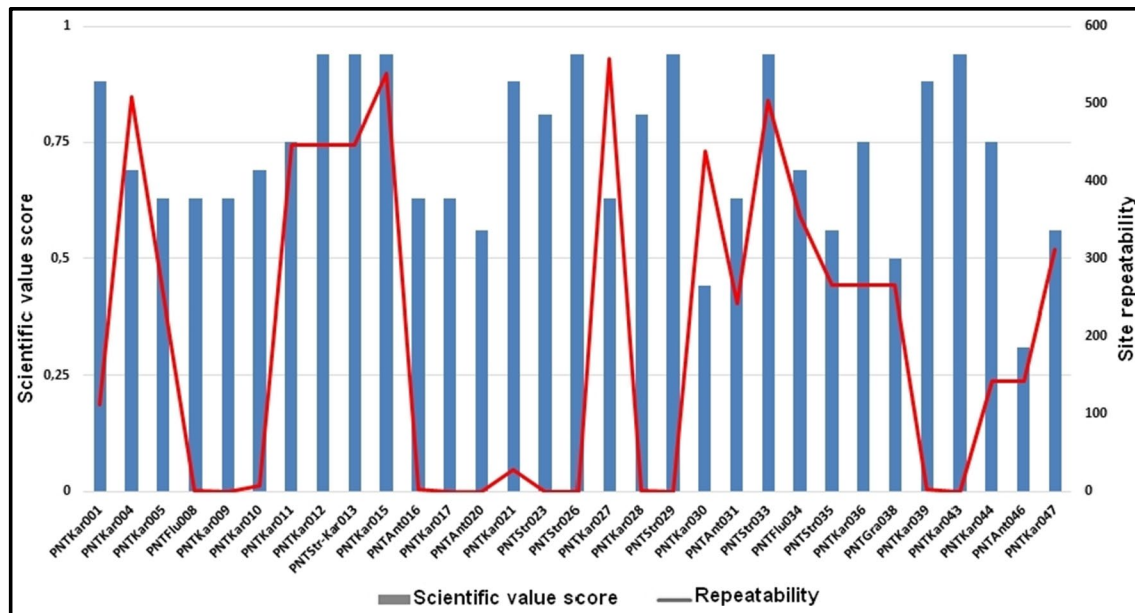


Fig. 14 Relationship between scientific value and social value

high scientific value and very low or absent repetitiveness, exemplified by proposed geosites unknown to local actors (Bab Boudir anticline (TNPSr023) and Jbel Bou Massoud (TNPSr026), the Dhar Feurn waterfalls (TNPKar028), the volcano-sedimentary complex (TNPSr029), and the field of fossilized lapies of Jbel Bou Massoud (TNPKar039) and Tighigha (TNPKar043)).

On the contrary, certain geosites exhibit an exceptionally high repetitiveness, surpassing 400 times. Examples include the Bab Boudir complex, celebrated by the Boudir summer center, with a repetitiveness of 558 times, the Friouato chasm (538 times), the resurgence of Ras El Ma (509 times), the massif of Tazekka (503 times), the sinkhole, polje, and ponor of Dayat Chiker (446 times), and the Ain Admame emergence (439 times). Despite being the most well-known and frequently visited sites, these geosites have not undergone any development or tourist enhancement, except for the center of Bab Boudir.

Undoubtedly, the social dimension must be considered in any development and regional planning policy. This dimension provides a clear understanding of the level of appropriation and knowledge of these geosites by the local population and various stakeholders (Hili and El Khalki 2017). Such appropriation not only fosters a sense of affection and attachment to these geosites but also initiates a process of heritage development among the local population and the various stakeholders in this entire territory.

## Discussion

### Contribution of the Study for TNP Managers

Based on these findings, it is evident that the inventory, evaluation, and cartography conducted have unveiled the wealth of high-quality geosites within the Tazekka National Park (TNP), including Ras El Ma waterfalls and source, Friouato abyss, Dayat Chiker polje and abyss, El Qelaa complex, Jbel Bou Massoud and Tighigha fossils, Tazekka massif, Tighigha complex, and more. These geosites deserve to be publicized, protected, and valued. The integration of the social dimension has revealed the hidden and neglected aspects of these geosites.

The inventory and evaluation work has demonstrated that the geosites in Tazekka National Park exhibit complexity and a variety of forms that can serve as the cornerstone for geo-eco-cultural-tourist development in this area. The objective is to inform the public about the current status of these geosites, aiming to raise awareness and encourage public participation in the protection and enhancement of the park. The goal is to contribute to the popularization of this theme by emphasizing concepts such as geo(morpho)logical heritage, geosites, and conservation to enhance awareness and promote landscape culture.

To maximize the utility of this study, the evaluation results are presented in the form of summary maps, offering

a relevant foundation for intervention. This presentation encourages responsible authorities to establish a working group, initiating a comprehensive project encompassing inventory, cartography, protection, and valorization of geosites at both regional and potentially national scales. This approach aims to extend the geopark concept to other Moroccan regions rich in geoheritage, biodiversity, cultural diversity, and history.

The summary maps serve as valuable tools for management and decision-making. They enable targeted and efficient development efforts, offering essential information to park managers for implementing policies focusing on the management, protection, and enhancement of these geoheritages. Moreover, they play a crucial role in raising awareness among the general public, fostering a deeper understanding of their heritage rich in geodiversity, biodiversity, and cultural diversity.

In the context of sustainable development, preventing the degradation of the natural and cultural geosites classified as nationally and/or regionally significant is imperative. A robust legislative framework is urgently needed to manage and ensure the genuine protection of nature and landscapes. Furthermore, inventory, evaluation, and enhancement studies on geodiversity, in general, and geosites, in particular, should be extended regionally and nationally. This would facilitate the inventorying, mapping, protection, preservation, and improved management of these sites, integrating them into all public land-use planning policies.

### Methodological Contribution of the Work

From a methodological standpoint, this research contributes to the improvement of cultural value evaluation, an aspect often overlooked and previously assessed through a single sentence. The inclusion of the social dimension in this evaluation, reflecting the traditions, identity, and legends of the local population along with the landscape's characteristics, emphasizes the importance of considering this dimension in any development and land-use planning policy. It serves as a key variable to understanding the degree of appropriation and knowledge of these geosites by the local population and various managers.

The qualitative data analysis revealed a diverse and fascinating natural and cultural heritage in the Tazekka National Park. Local actors' preferences for certain well-known geosites underscore their significance. This is a crucial indicator that aids in the protection and conservation of these geosites. These findings affirm that integrating the social dimension is essential for ensuring the involvement of the local population. This involvement is vital in minimizing the negative impacts of tourism on geosites and the region, ultimately presenting a tourism product geared towards improving the socio-economic conditions of the local population.

The methodological contributions of this study are meaningful when applied urgently. The research establishes a typology of geosites, providing a foundation for a more targeted intervention strategy. The study also offers the park manager scientific support for a new vision of management, protection, and enhancement of the natural and cultural potential. Based on the inventory and evaluation of the geosites in the Tazekka National Park, a comprehensive scientific and geodidactic valorization is necessary. This should consider all geological, biological, and cultural components of the territory. The aim is to showcase the richness of the park's territory and the heritage value of its geological and geomorphological features, as well as to highlight the threats (both natural and anthropogenic) affecting this geoheritage. Proposed valuations, to be discussed in another article, will focus on the relationship between visitors and the knowledge to be transmitted. The goal is to mitigate threats and increase awareness among the stakeholders.

### Conclusion

The main objective of this work is to inventory, evaluate, and map the geosites of the Tazekka National Park (TNP) in the Middle East Atlas, Morocco. Across the entire territory, we have identified 31 geosites of different types of processes (karst, structural, structural-karst, fluvial, gravitational, and anthropogenic).

The inventory results demonstrate that the TNP is a territory with significant geological and geomorphological potential. The majority of assessed sites exhibit considerable scientific and ecological value, emphasizing their importance for biodiversity and the ecosystem. However, a few sites have lower values, underscoring the need for special attention to ensure their protection and preservation. Additionally, the size of geosites appears to be a crucial factor in their perceived aesthetic value. Larger sites are often associated with higher aesthetic value, suggesting that emphasizing these visually impactful sites can guide strategies for their preservation and enhancement.

From a social and cultural perspective, the sites recommended by local actors play a pivotal role in the identity of the local population. Their high cultural value, linked to traditions and community history, underscores the importance of these sites as key elements of local heritage. Integrating these geosites into tourist circuits could not only promote their protection but also contribute to the economic development of the region while preserving its cultural identity.

The tourist potential of this park is notable but requires the adequate protection of sites and awareness raising among local stakeholders to preserve these natural resources. The study proposes measures to minimize the negative impacts of tourism, create a tourism product

favorable to local development, and launch a national project to inventory, protect, and promote geosites across Morocco. In conclusion, this study highlights the importance of the geosites of Tazekka National Park, emphasizing their scientific, ecological, aesthetic, social, and cultural value. It recommends preservation and enhancement measures to make them sustainable assets for the region and the country.

**Data Availability** Data availability All the data are included in the present study.

## Declarations

**Conflict of Interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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