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A quantitative method for inventory and assessment of geoheritage in the Beni Mellal Atlas Mountains, Morocco

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A quantitative method for inventory and assessment of geoheritage in the Beni Mellal Atlas Mountains, Morocco

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O metodă cantitativă de inventariere şi evaluare a geopatrimoniului în munţii din Maroc: studiu de caz al sinclinalului Tagleft din Atlasul Beni Mellal. Acest articol propune o metodologie cantitativă pentru identificarea şi evaluarea siturilor geologice şi geomorfologice din sinclinalul Tagleft. Această metodă propune noi criterii de evaluare relativ conforme cu caracteristicile muntelui marocan, făcând referire la diferitele metode care au fost deja realizate în ţările europene. Obiectivul este astfel de a reduce la maximum subiectivitatea evaluatorului, de a clarifica în profunzime criteriile care compun valorile de evaluare (valoare ştiinţifică, valori suplimentare şi valoare de utilizare). În final, această metodă este aplicată pe siturile geologice și geomorfologice din sinclinalul de la Tagleft, Atlasul Beni Mellal, Maroc.

Cuvinte cheie: geoeritage, inventariere, evaluare, sinclinalul Tagleft.

A quantitative method for inventory and assessment of geoheritage in the mountains of Morocco: a case study of the Tagleft syncline in Beni Mellal Atlas. This article proposes a quantitative method for the identification and assessment of geological and geomorphological sites in the Tagleft syncline. This method proposes new criteria of evaluation relatively in conformity with the characteristics of the Moroccan mountain by making reference to the various methods which were already carried out in the European countries. The objective is thus to reduce the subjectivity of the evaluator, to clarify deeply the criteria composing the assessment values (scientific value, additional values and use value). This method is finally applied on the geological and geomorphological sites of the syncline of Tagleft, Atlas of Beni Mellal, Morocco.

Keywords: geoheritage, Inventory, Assessment, Tagleft syncline.

1. INTRODUCTION

Since the end of the 1990s, awareness of the importance of geological and geomorphological sites has become a worldwide reality, especially in Europe (France, Switzerland, Germany and Portugal). Various studies have attempted to highlight the scientific values as well as the socio-cultural and economic functions of geological and geomorphological sites, which "group together assets of a geological (rocks, minerals, fossils), geomorphological (landforms), pedological (soils) and hydrological (rivers, lakes, groundwater) nature, while at the same time attaining the status of territorial resources on which to base local development actions" (Bétard et al., 2017; Hobléa et al., 2017).

The interest in geological and geomorphological sites (geosites and geomorphosites) stems from their scientific, ecological, aesthetic, socio-cultural and economic value. This "multi-value" approach is the one that will be adopted in this work since the study is directed towards geoheritage enhancement and the promotion of leisure and sport tourism. These different values can be considered as the components of the tourism value of geo-heritage: "This integrated and systematic approach shows the possible synergies of enhancement between geological and geomorphological, bioecological and historical-cultural heritage. The use of these values by man can initiate different uses (landscape resources, economic and educational element)" (Pralong, 2006; Figure 1).

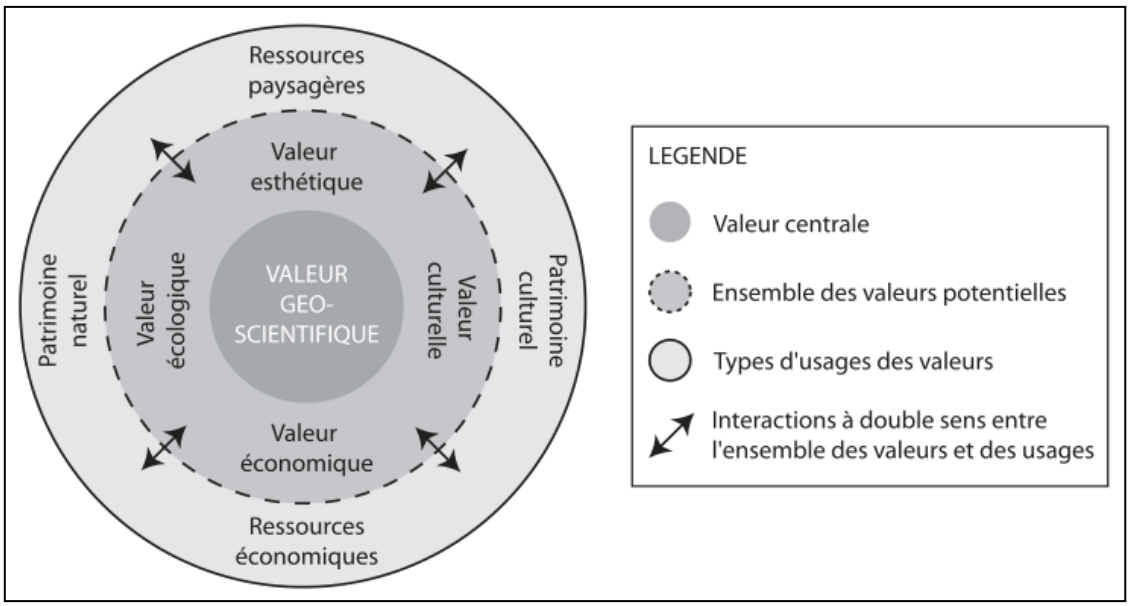

Figure 1. Geoheritage values (Pralong, 2006)

In this global context, Morocco has begun to concern itself with its geoheritage sites especially with the creation of the M'goun Geopark, in 2004 labelled by UNESCO in 2014 and revalidated in 2019, which hosts a remarkable geodiversity of the Central High Atlas in which this geopark is located, recognized by the Ibakaliwn dinosaur tracks, the famous Ouzoud waterfalls and the Imin Ifri natural bridge (Cayla and Duval, 2013).

This study aims to present, in detail, and apply a new method of inventory and evaluation, adapted to the Moroccan context, which allows to assess the geoheritage value of the geosites and geomorphosites that characterize the Tagleft syncline, which is in the Atlas Mountains of Beni Mellal, Morocco, with a view to enhancing the tourism value of this territory.

2. STUDY AREA

The Taguelft syncline is located in South of the Béni Mellal city, extending from Taguelft village in the North-East to the Tabaroucht locality in the South-West. The Tagleft Syncline presents one of a large synclines in the high mountains Atlas of Morocco, filled by red continental formations of Bathonian age, and crossed by Oued El Abid river from the North-East to the South-West. It is resulting from Triassic and Middle Jurassic rifting, allowed a wide diversity of detrital sedimentation (Haddoumi et al., 2010). During the Middle and Upper Jurassic, fracturing caused significant differential subsidence resulting in flat-bottomed synclines, which received the Upper Jurassic and Cretaceous red beds, and the uplift of the Liassic ridges (Löwner, 2009) (Figure 2, Figure 3).

3. METHODOLOGY

Numerous methods of inventory and assessment of geosites and geomorphosites have been developed worldwide (Grandgirard, Vincent, 1997; Reynard et al., 2007; Serrano, Trueba, 2005; Rybar, 2010; Kubalikova, 2013; Pralong, 2006; Zouros et al., 2007; Ielenicz, 2009; Pereira, 2010; Tomić, Božić, 2014; Iosif, 2014).

For the study of the geosites and geomorphosites of the Tagleft syncline, we have developed a new systematic method, easily applied, referring to the other mainly European methods previously mentioned, defining new variables that we think are more suitable for our study area. The inventory and evaluation methods are based on criteria for calculating site values. Three different values have been characterized (Figure 4, i) the geoscientific value is the most important one, as a geomorphological and geological landscape contains visible traces of the geological history of the earth and the paleoclimate.

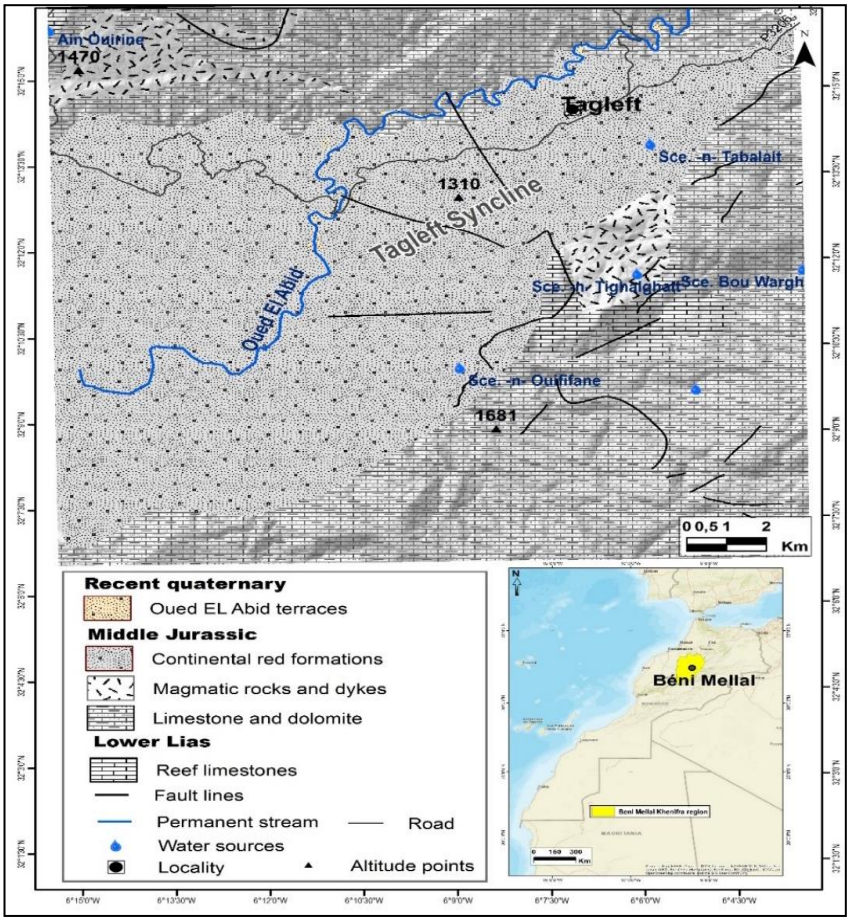

Figure 2. Localization of Tagleft syncline and its geology in the Béni Mellal Atlas

Figure 3. Panoramic view of the Tagleft basin, crossed by the Oued El Abid (Ait Omar, 2021)

In addition, there are (ii) additional values that determine the ecological value by showing the close relationship between abiotic and biotic nature. It may also have an aesthetic or scenic value through its 'beauty' or spectacular character. It can also be charged with historical and religious values giving it a cultural value and an iconographic analysis is also essential that confirms the artistic interest of a geomorphosite (Ait Omar et al., 2019 b). It is also considered as a social object that presents a sentimental place and belonging for a given society. For this purpose, we conducted a questionnaire survey among territorial actors to arise the social fame of the geosite or geomorphosite (Hili, El Khalki, 2017; Ait Omar et al., 2021). Finally, according to iii) the use value, a geosite or geomorphosite can be used as an economic resource, notably by tourism, agriculture (irrigation) or extractive activities (quarries, mines).

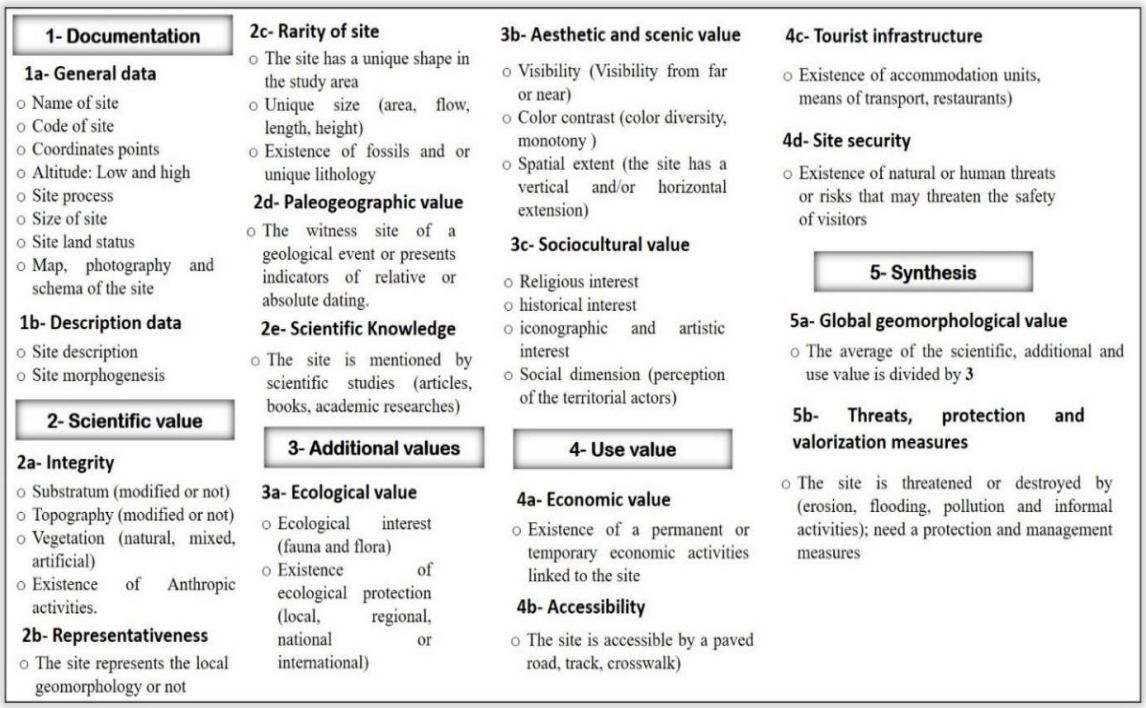

Figure 4. Steps for the inventory and assessment of geoheritage in Moroccan context

3.1. Documentation data

The developed method consists of three evaluation parts. The first part will assess the scientific value through the criteria: integrity, representativeness, rarity, paleogeography and scientific knowledge of the site). The second part will assess the socio-cultural, ecological and aesthetic aspects. The third one evaluates the use value of the site by assessing its economic interest, accessibility, tourist infrastructure and safety). The range of scores given respects the weight of each criterion, the evaluation elements of each variable that have the same weight get the same score, on the other

hand, the proportional sub-variables have hierarchical scores between (0-0.25-0.5-0.75-1) or between (0-0.5-1).

3.1.1. General and descriptive data

For each geomorphosite or geosite surveyed, a detailed inventory sheet was produced, including a set of general data on location, elevation, type and land status of the site. photography, maps, diagrams represent the site are also collected. Descriptive data are collected from field observation and bibliography (Table 1).

Table 1. General data, description and morphogenesis

Descriptive data	Description	Morphogenesis
Code and Name of the site Geographical coordinates Elevation (m): Min - Max Morphogenic type Size of the site Land status of the site Map, diagram, photography	Take field observations as well as already existing information from the (scientific or general) literature about the site. The general data as well as the geological, ecological, or cultural particularities related to the site are collected.	Processes responsible for the development and the stages of the geomorphological history that led to the establishment of the inventoried geosite are described here. If the site is anthropogenic, a short historical description is given

3.2. Assessment of scientific value

To assess the importance of this value for each of the inventoried sites, the present methodology is based on five criteria: integrity, representativeness, rarity, palaeogeographical value and scientific knowledge. Each of these criteria is assigned a score, between 0 and 1.

3.2.1. Integrity

Integrity corresponds to the state of conservation of the geomorphosite. The integrity of the site concerns not only the geotope in the strict sense, but all the elements surrounding this geotope according to the broad definition of geomorphosite. It is considered intact if its natural components (bedrock, topography, vegetation) are also intact and thanks to the absence of anthropogenic activities (Table 2).

Table 2. Criteria for assessing the integrity of geoheritage

Integrity	Description	Score (0-1)
Substrate	Unchanged	1
	Partially changed	0.5
	Completely changed	0
Topography	Unchanged	1
	Partially changed	0.5
	Completely changed	0
Vegetation	Natural	1
	Natural and artificial	0.5
	Artificial	0
Anthropization	Absence of anthropogenic activities	1
	Partially equipped	0.5
	Fully equipped	0

3.2.2. Representativeness

This criterion is used in relation to the reference area of the study. According to this criterion, the geomorphosites selected must be representative of the geomorphology of the studied region. "They should cover the main processes, active or passive, of the region" (Reynard, 2007). To this end, we based ourselves on three cases. A site resulting from the action of several geomorphological processes will have the highest score. For example, a karst spring is also having a structural origin (springing from a fault). A site may also be characterized by several associated processes and forms, such as a polje associated with other forms such as sinkholes, etc. The second case, with an intermediate score, occurs when there is only one process responsible for the morphogenesis of the site. For example, a sinkhole is shaped by a single process, the karst process. The third case is where the morphogenesis of the site is not representative of the study area, such as geomorphological sites of anthropogenic origin. The determination of this representativeness is based on the statements of scientific experts, especially from the literature on regional geomorphology (Table 3).

3.2.3. Rarity (uniqueness)

In contrast to the previous criteria, this criterion evaluates the rarity of the object, always in relation to the reference area. It makes it possible to highlight the forms and processes that are exceptional and rarely represented in the study area (Reynard, 2007). The elements adopted to evaluate this value are the form, which is classified as exceptional or common by referring to a typology of forms pre-established for the study area, where the number of similar sites per process was counted. The second variable

used to assess rarity is the size of the object, or the flow in the case of springs. A canyon with a remarkable height or a spring with a high flow rate will be considered unique compared to others (Table 4).

Table 3. Representativeness of geoheritage

Variable	Description	Score (0-1)
Exemplarity of the site	The site is the origin of multiple geomorphological processes	1
	The site is one of the geomorphological processes marking the regional geomorphology	0.5
	The site does not represent the regional geomorphology.	0

Table 4. Criteria to assess the rarity of geoheritage

Criteria	Description	Scores 0-1)
Form	Unique	1
	Not important	0
Size or flow	Unique	1
	Not important	0
Fossils and/or rare lithology	Presence	1
	Absence	0

3.2.4. Paleogeographic value

Some geomorphological objects are irreplaceable witnesses of the Earth's history. Their palaeogeographical value depends on the information they are able to provide (Grandgirard, 1997). To characterize this palaeogeographical value, we rely on the existence of relative or absolute dating elements, for example fossils, ancient river deposits, concretions in caves, etc. A site that bears witness to a geological event, such as a tectonically uplifted rock, will also be an indicator to be taken into account, but with a lower score. The assessment of this value is based on the opinions of expert geologists, geomorphologists and geographers (Table 5).

3.2.5. Scientific knowledge

It is assessed on the basis of the place of the geological or geomorphological object in the scientific field and the interest it has aroused in scientific studies, in particular, its presence or absence in i) scientific works (articles, books, scientific dissertations) (Rybar, 2010; Kubalikova et Kirchner., 2013, 2015) and ii) the type of publication

mentioning the geomorphological site, national and/or international, is also an important criterion. Sites mentioned in both national and international works are of high scientific importance and have a high score (Table 6).

Table 5. Criteria to assess the paleogeographic value

Criteria	Description	Scores (0-1)
Dating Indicator	Presence of relative or absolute dating indicators	1
	Witness to a geological event	0.5
	Absence of dating Indicator	0

Table 6. Scientific knowledge criteria

Criteria	Description	Scores (0-1)
Number of scientific articles and/or books and/or dissertations	More than two	1
	One to two	0.5
	No articles and books	0
Type of publication	International and national	1
	International	0. 5
	National	0.25
	None	0

Average scientific value: (Integrity) + (Representativeness) + (Rarity)+ (Paleogeography)+ (Scientific knowledge) / 5.

3.3. Assessment of additional values

Three additional values have been assessed: ecological, aesthetic, socio-cultural (Reynard, 2007, 2016, Iosif, 2014).

3.3.1. Ecological value

There is a clear link between biotic diversity (biodiversity) and abiotic diversity (geodiversity), the latter being the essential support for the former (Bétard, 2011). Geodiversity has an important ecological role in supporting biodiversity, and in the functioning of ecosystems (Crofts, 2019). The assessment of ecological value is based on two criteria: i) biological interest (plant and animal). This interest can be high when a geosite or geomorphosite allows the development of endemic and rare species. On the other hand, its interest decreases when it only allows the development of common species already present in the studied area. The assessment of biological interest is based on field observation, research on biodiversity (Flora and Fauna) in Morocco (Aafi

et al., 2002) and reports on Sites of Biological and Ecological Interest (SIBE) in Morocco, as well as on the mapping of the vegetation cover of the Tadla Azilal area (Taïbi et al., 2015). It should be noted that several fauna and flora species of different importance (local, regional, national or international) can be found in the same site. The score corresponding to the most important species present was therefore assigned. ii) Ecological protection determines the level of protection of the geosite or geomorphosite, particularly in the context of a nature reserve, which a priori attests to its ecological interest. In fact, there are sometimes geosites or geomorphosites that are ecologically important but are not included in protected areas, so they are given a "zero" (Table 7).

Table 7. Criteria for assessing ecological value

Criteria	Description	Scores (0-1)
Biological interest: Plant and/or animal	Common species	0.25
	Species of regional and or local importance	0.5
	Species of national importance	0.75
	Rare and endemic species of international importance	1
Ecological protection	No protection	0
	Local protection	0.25
	Regional protection	0.5
	National protection	0.75
	Global protection	1

Average ecological value: (Biological interest) + (Ecological protection) / 2.

3.3.2. Aesthetic value

Several geosites or geomorphosites have visual characteristics, which give them a big landscape relevance in the definition of visibility conditions (viewpoints), sites visible from a distance have the great touristic importance, given their landscape beauty, colors contrast with the environment and their spatial extent (Table 8).

3.3.3 Socio-cultural value

The socio-cultural importance of geoheritage is reflected in the intimate relationship between human being and the natural environment in general and the abiotic elements. In this case, „the cultural value of geoheritage may be studied from three main points of view. Geoheritage, as other types of natural heritage, can be considered as part of the cultural heritage in a broad sense of a society, a nation or humankind. The study of the relationships between culture and geology is the aim of

cultural geology and cultural geomorphology. Culture influences Earth system management, mainly through the perception of Earth, itself depending on immaterial cultural elements such as values, symbols, and traditions" (Reynard, Guisti, 2018: 153-154). The variables used to characterize this socio-cultural value relate to historical and archaeological, religious, and symbolic, artistic, iconographic and literary dimensions, as well as the social perceptions.

Table 8. Criteria for assessing Aesthetic value

Criteria	Description	Scores (0-1)
Visibility	Visible in-place	0
	Visible from a far distance	1
Colors contrast	Absence	0
	Presence	1
Spatial extent	Not important	0
	Vertical	0.5
	Horizontal	0.5
	Vertical and horizontal	1

Average aesthetic value: (Visibility) + (Colors Contrast) + (Spatial extent) / 3.

a) Historical and archaeological dimension

Sites that have experienced historical events and/or contain historical and architectural monuments and/or archaeological remains such as formerly inhabited caves or caverns, abandoned mines, or the site of a historical event, will have an increased socio-cultural value. It should be noted that the scores for this variable may be added together when the site is characterized by several of these historical elements.

b) Religious and symbolic importance

The socio-cultural value will also be linked to the religious and symbolic functions of geoheritage as places of worship in caves or near springs, waterfalls or rock shelters etc. Some springs have a sacred character, and are therefore associated with regulated practices, notably for health reasons (e.g. treatment of diseases). Some sites also have a symbolic value, such as a ridge line or a river marking a property or administrative boundary.

c) Artistic and iconographic importance

The existence of artistic productions (paintings, poems, stories and music), representing or evoking a geosite, for the beauty of the landforms or because of a particular sentimental relationship of the author. The iconographic importance is based on the collection of photos posted on Google Earth and Google Map for regional geosites. This new technique is experimented in this work, to evaluate the iconographic

importance of the geosite or geomorphosite, specifically by the criterion "photographic shots" (Ait Omar et al., 2019b).

d) Social dimension or social perception

Knowing that "Any representation or social perception is therefore a cognitive process of mental elaboration, certainly personal, but largely influenced by collective aspects, so that the analysis of individual representations can reveal the effects of structures linked, for example, to a social, political or territorial belonging common to certain groups "(Goeldner-Gianella, Humain-Lamoure, 2010: 327). We integrated the perceptions of geological and geomorphological objects by different stakeholders (inhabitants, visitors, elected officials, tourism and geopark managers and owners of gites and tourist guides) (Hili, El Khalki, 2017; Ait Omar et al., 2021) through a questionnaire survey that includes closed and/or open questions, which question the imaginary, opinions, and preferences (known geosites, preferred landscape elements in the visited geosite, means of transport used, nature of visit) towards the geoheritage of the Atlas of Beni Mellal. 400 respondents were surveyed: 233 inhabitants (58.3%), 136 visitors (34%), 11 accommodation owners (2.7%) and 10 associations (2.5%). Eight elected representatives were also interviewed, representing 2% of those surveyed, and two managers of the structure responsible for managing the M'goun Geopark (0.5%). From these survey data, we were able to define a scale to classify the sites studied (Table 9).

Table 9. Scale for assessing the social perception of the studied sites

Percent of occurrences with respondents	Level of knowledge of the site	Score (1-0)
The site is not cited	Unknown	0
The site is cited between 1 and 25%.	Little known	0.25
The site is cited between 26% and 49%.	Moderately well known	0.5
The site is cited by 51-74%.	Known	0.75
The site is cited 75% and more	Well known	1

3.4. Assessment of use value

In a perspective of geotourism valorisation, beyond the economic value (economic interest), we added criteria related to the conditions of visit especially in relation to the tourist attractiveness such as: accessibility, tourist infrastructure (means of transport, existence of accommodation units, existence of restaurants) and finally the safety of sites (Ielenicz, 2009; Rybar, 2010; Pereira, Pereira, 2010; Kubalikova, 2013; Reynard et al., 2016).

Table 10. Criteria used to assess socio-cultural value

Criteria	Description	Score (0-1)
Religious interest	Ordinary	0
	Religious holidays	0.5
	Sacred place and other beliefs related to the site	0.5
Historical and archaeological interest	Ordinary	0
	Presence of architectural sites around the site	0.25
	Place of a historical event or place to exercise customs related to its exploitation (agdals, irrigation customs)	0.25
	Archaeological remains	0.25
	Presence of myths or legends	0.25
Artistic and literary interest	Ordinary	0
	Existence of photographic shots	0.5
	Presence of poems, paintings and/or songs	0.5
Social perception	The site is not well known	0
	The site is not well known	0,25
	The site is moderately well known	0,5
	The site is known	0,75
	The site is well known	1

Average socio-cultural value (Religious interest) + (Historical and archaeological interest) + (Artistic and literary interest) + Social perception /4.

Average of additional values (Ecological value) + (Aesthetic value) + (Socio-cultural value) /3.

3.4.1. Economic interest

The economic importance is assessed through the presence of economic activities, related to the exploitation of the site but also the nature of these activities. The permanent activities can ensure permanent earnings for the local population, so the site is very interesting from an economic point of view. On the other hand, the presence of temporary activities will reduce the economic importance of the site (Table 11).

Table 11. Criteria for assessing the Economic value

Criterion	Description	Scores (0-1)
Economic activity	No economic activity	0
	A single activity	0.5
	Several activities	1
Type of activity	Permanent	1
	Permanent and temporary	0.5
	Temporary	0.25

3.4.2. Accessibility

It is assessed according to the type of road that provides access to the site. It can be a footpath, a track or a tarmac road, sometimes all at the same time, which requires us to keep the category with the highest score (Table 12).

Table 12. Accessibility sclae

Description	Scores (0-1)
No accessibility (isolated site)	0
Accessible only by a footpath	0.25
Accessible via a track	0.5
Accessible by a paved road	1

3.4.3. Tourist infrastructure

The existence of tourist infrastructure, transport, accommodation and restaurants, are also basic elements favouring the attractiveness of visitors to explore natural sites, including abiotic objects. Their absence creates unfavourable conditions for the frequentation of places, even those with beautiful landscapes. i) the existence of means of transport ii) the existence and diversity of accommodation units is fundamental and their distance, knowing that the site with in-situ and/or nearby accommodation takes a high to medium score compared to the one where accommodation is far away (more than 10 km) and ii) the presence of restaurants, but they can often be found associated with accommodation units, which implies reducing the score to 0.5 instead of 1 (Table 13).

3.4.4. Site security

This criteria makes it possible to identify the sites which an exploitation for geotourism purposes represents the least risk for visitors. These risks can be of natural origin (risk of rockfall, landslides, steep passages), sometimes meteorological risks (risk of storms in high plateaus and risk of flooding in gorges and canyons) and social risks, linked to the existence of dangerous social practices (the spread of the crime of theft and looting and all undesirable practices; Table 14).

3.5. Summary of the geoheritage assessment

The last step of this analysis is a synthesis of the previous evaluations, allowing the overall value of the geological and geomorphological object to be calculated, but also to identify existing and/or potential threats and to propose measures for protection and enhancement.

Table 13. Tourism infrastructure criteria

Criteria	Description	Scores (0-1)
Means of transport	Lack of transport facilities	0
	Mule and donkey hire	0.25
	Presence of public transport	0.5
	Presence of public and private transport	1
Presence of accommodation units	No	0
	One to two	0.5
	Several units	1
Distance from accommodation units (km)	Far (more than 10 km)	0
	Nearby (less than 10 km)	0.5
	In-situ	1
Type of accommodation	Possibility of camping	0.25
	Presence of inns and gites	0.5
	Presence of guest houses and hotels	0.75
	Several types of accommodation	1
Existence of restaurants	No restaurants	0
	Presence of restaurants	0.5

Table 14. Assessement security scale

Description	Scores (0-1)
Presence of natural and social risks	0
Presence of natural or social risks	0.5
No risk	1

Average of use value: (Economic interest) + (Accessibility) + (Tourist infrastructure) + (Site security) /4.

3.5.1. Overall geomorphological value

It is the average of the scientific value, the selected additional values and the use value. It is calculated as follows: Overall geomorphological value = (Scientific value) + (additional values) + (use value) /3.

3.5.2. Threats and proposals for protection and enhancement

Several geosites and geomorphosites are currently subject to existing or potential threats, which are related to natural forces such as flood risk, erosion in general (by various processes). Anthropogenic forces can also occur, either together with or independently of these natural hazards. These include overexploitation of natural

environments in general, and geomorphosites in particular, pollution, etc. In this context, measures to protect these sites can be proposed as a response to the vulnerability of this heritage, which is considered as non-renewable. In terms of enhancement, some geomorphosites have a very strong geotourism and educational potential, which requires the proposal of tourism and geodidactic enhancement measures.

4. RESULTS AND DISCUSSION

4.1. Geographical description of the selected sites

The Tagleft syncline is characterised by 04 geopatrimoines of local importance. The first site corresponds to a karstic spring which gushes out on its south-western edge. The second concerns spectacular meanders in its central part and basaltic intrusions on its northern edge and finally an anthropic geomorphosite called "Granaries of the cliff of Walous" (Figure 5, Table 15).

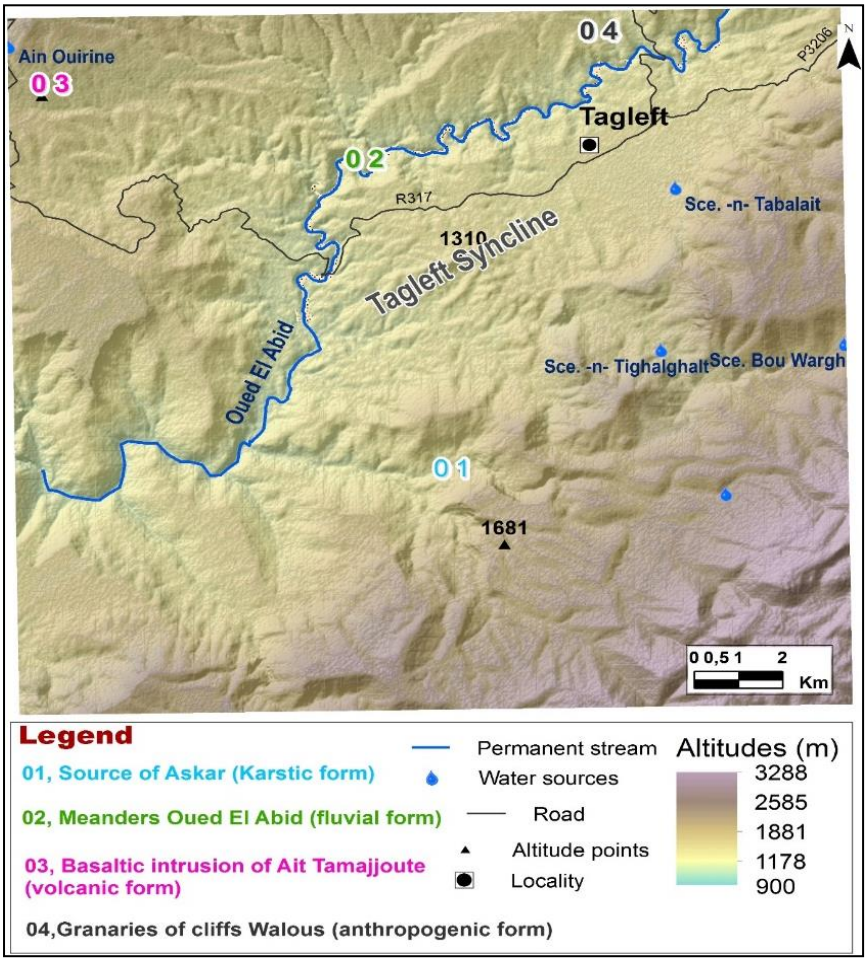

Figure 5. Localization of studied geoheritage sites per process

4.2. Analysis of the scientific, additional and use value

From the assessment results, we can say that **i) the scientific value** of all the sites studied has an average of (0.53). The sites record a high scores exceeding the average, especially the basaltic intrusion of Ait Tamajjoute (0.70), the karstic spring of Askar (0.69) and the meanders of the oued El Abid (0.52), whereas the cliffs attics show a low scientific interest with a score not exceeding (0.20). This scientific importance is due, firstly, to a high integrity (0.65) where most of the sites retain their natural characteristics and are little denatured. Secondly, thanks to their rare characteristics (0.64) resulting from their size or their unique lithology in the studied territory as well as their important palaeogeographic value (0.62) attached to the dating indicators they offer, especially the basalt intrusion which has been dated between 170 to 110 million years before the present (Guezal et al., 2013) and the terraces on the Oued El Abid which indicate the important fluvial dynamics during the wet period of the recent quaternary. On the contrary, the scientific interest is influenced by a low scientific knowledge (0.34) and a low representativeness (0.37) because the sites are not part of the karstic geomorphological process considered as main in the study area except for the Askar karstic spring.

As for the ii) additional values, most of the sites studied have a landscape interest that remains low compared to the scientific value (central). The additional value does not reach the median (0.47) because the studied sites only allow the development of vegetation of local importance: thuja, carob tree, holm oak, olive tree, oleander, almond tree, fig tree, walnut tree... as well as common animal species: green butterflies, local birds (garden bulbul, grey flycatcher; rock pigeon) and for the socio-cultural value which is quite low (0.32) with the exception of the Askar spring which is a sacred spring, its water treats kidney disease and there are sayings about it that "drinking water from the water mill allows girls to mary", local historical monuments are linked to the spring: collective granaries, traditional mill and Sidi Hsayn marabout. Its water is managed traditionally, for irrigation and photographed several times by visiting photographers and thanks to its low social reputation (0.25). On the other hand, the aesthetic value is remarkable (0.62), which is mainly linked to the landscape diversity (contrasting colours of the water, vegetation, rocks and traditional buildings).

Concerning iii) the use value of the selected sites is important, reached (0.60) because they allow the development of several economic activities (0.55). All of the sites contribuate to an local tourism and others allow for local agricultural development (Askar spring and the meanders of the Oued El Abid). They present the safe visiting conditions (1) and they are all accessible (0.69), but poorly equipped, with an average score of (0.44) for the touristic infrastructure.

Table 15. Describing of geological and geomorphological sites

	**1. Ain Askar spring:** Located at douar Askar (32.165777 N; -6.157172 W; altitude, 1225 m, max flow: 400 l/s). This spring is fed by the Lias karstic aquifer. It emerges at the foot of a marly-limestone wall and is fed by rainwater and snowfall, infiltrated through various loss points upstream (the Jbel Chitou karst at over 2600 m). Its water is used for the irrigation of olive trees and orchards and also for food (Marabout of Sidi Hssyn, collective granaries and traditional mill). A touristic attractive is observed especially in spring and summer.
	**2. Manders of the Oued El Abid** (32.235483 N; -6.180339 W, altitude 996 m**):** Located 8km from Tagleft. They are characterized by a diversity of landscapes (agricultural terraces, traditional houses, marabouts, muskets, bridges, red juniper, inns…). The El Abid wadi crosses the Tagleft syncline...and draws longitudinal swales adapted to a differential erosion relief (Couvreur, 1988) by forming real meanders. Deposits are made on the convex bank, where the speed of the current is the lowest, forming an alluvial terrace (or meander bar).
	**3. Basalt intrusions of Ait Tamajjoute and dyke**: (32.25382 N; -6.261773 W, altitude 1591m). They occur in all the synclinal basins of the Beni-Mellal Atlas. They are linked to the geodynamic stages of the region, initiated by the rifting of the Atlantic Ocean. Their age (170 to 110 million years) was determined by radiometric dating methods on basaltic flows by the K/Ar method or on total rock or on plagioclases (Monbaron, M, 1980 and Guezal et al., 2013).
	**4. Walous Cliffs**: (32.29416111N;-6.110466667, altitude 1368m). The Walous granary cliff is located to the north-east of the Tagleft village. These granaries are built on a beige limestone cliff from the Middle Jurassic. This cliff of Walous, constitutes an anthropic geomorphosite where man has built small houses to protect his crops against local enemies during conflicts between tribes.

Finally, the analysis of the overall geomorphological value (0.54) shows that the sites studied offer a very diversified assets and have a certain potential for geotourism and geodidactic development (Table 16).

Table 16. Assessment results of geosites and geomorphosites studied

Geoheritage values and its criteria	Source of Askar	Meanders Oued El Abid	Basaltic intrusion	Granaries of cliffs Walous	Average
1- Scientific value	**0.69**	**0.52**	**0.70**	**0.20**	**0.53**
1-a Integrity	0.62	0.75	0.75	0.5	**0.65**
1-b Representativity	1	0.50	0	0	**0.37**
1-c Rarity	0.58	0,50	1	0.5	**0.64**
1-d Paleogeography	1	0.50	1	0	**0.62**
1-e Scientific knowledge	0.25	0.37	0.75	0	**0.34**
2- Additional value	**0.52**	**0.41**	**0.37**	**0.58**	**0.47**
2-a Ecological interest	0.5	0.42	0.5	0.42	**0.46**
2-b Aesthetic value	0.5	0.5	0.5	1	**0.625**
2-c Socio-cultural value	0.56	0.31	0.12	0.31	**0.325**
3- Use value	**0.69**	**0.52**	**0.7**	**0.49**	**0.6**
3-a Economic interest	0.75	0.75	0.37	0.35	**0.55**
3-b Accessibility	0.5	1	1	0.25	**0.69**
3-c Touristic infrastructure	0.4	0.7	0.3	0.35	**0.44**
3-d Security of site	1	1	1	1	**1**
4- Global value	**0.62**	**0.60**	**0.54**	**0.42**	**0.545**

5. CONCLUSIONS

Inventory and assessment are the first step certainly very important to make a geoheritage valorization. The geoheritage is considered as a resource for the development of the mountains and especially in Morocco through geotourism activities (educational tourism, sport and touristic trails).

The criteria proposed by the method developed in this work are inspired by previous methods already applied in inventory work in Western countries (France, Switzerland, Italy, Spain, Portugal, Czech Republic, Ukraine and others). The originality of this numerical method comes from the elaboration of easily usable criteria, based on field observation (integrity, aesthetic value), iconographic analysis and the social perception of the sites through a questionnaire survey addressed to the stakeholders. This numerical method aimed to reduce the subjectivity of the evaluation of the geotourism potential of the Tagleft syncline.

This potential will be the subject of a reflection on its valorization in the next research, relying on different means of popularization, such as didactic and geotouristic paths, brochures, referring also to the results of the questionnaire survey (on the touristic preferences of the local stakeholders) and to the communication with the civil associations.

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