

Methodological guidelines for geomorphosite assessment

Indications méthodologiques pour l'évaluation des géomorphosites

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Abstract

One of the most important issues in geomorphological heritage research is the development of methodologies that are focused on the evaluation of different types of value present in geomorphosites. A comprehensive methodology with different stages and approaches is presented. The method includes two main stages: inventory and quantification. The inventory stage includes four sub-stages: identification of potential geomorphosites; qualitative assessment; geomorphosite selection; geomorphosite characterisation. The quantification stage includes two sub-stages: numerical assessment; analysis of results. The interpretation of results for each of the indicators (scientific, additional, use and protection values) allows a comparison between sites and is of particular use in supporting site management decisions.

Key words: geomorphosites, assessment, criteria, methodology.

Résumé

L'une des priorités de la recherche sur les géomorphosites est le développement de méthodologies permettant l'évaluation des différents types de valeur des géomorphosites. L'article présente une méthode globale composée de différentes étapes et procédures. La méthode comprend deux étapes principales : l'inventaire et la quantification. L'étape d'inventaire est subdivisée en quatre sous-étapes : l'identification de géomorphosites potentiels ; l'évaluation qualitative ; la sélection des géomorphosites ; leur caractérisation. L'étape de quantification inclut deux sous-étapes : l'évaluation numérique et l'analyse des résultats. L'interprétation des résultats pour chacun des indicateurs (valeurs scientifique, additionnelles, d'utilisation et de protection) permet une comparaison entre les sites et peut être particulièrement utile comme outil d'aide à la décision.

Mots clés : géomorphosites, évaluation, critères, méthodologie.

Version française abrégée

Les géomorphosites sont des formes de relief qui ont acquis une valeur particulière en raison de la perception humaine (Panizza et Piacente, 1993). Cette valeur peut être d'ordre scientifique, écologique, culturel, esthétique et/ou économique (Reynard, 2005). Le développement de méthodologies d'évaluation des différentes valeurs des géomorphosites est l'une des préoccupations importantes de la recherche actuelle sur le patrimoine géomorphologique. Durant la dernière décennie, différents groupes de chercheurs ont proposé des démarches méthodologiques en vue d'évaluer, de comparer et de sélectionner les géomorphosites (Grandgirard, 1997 ; Rivas et al., 1997 ; Restrepo, 2004 ; Bonachea et al., 2005 ; Bruschi et Cendrero, 2005 ; Coratza et Giusti, 2005 ; Pralong 2005 ; Serrano et Gonzalez-Trueba, 2005 ; Reynard et al., 2007 ; Zouros, 2007). Dans ces travaux, l'accent a été mis principalement sur l'évaluation numérique des sites en vue d'accroître l'objectivité des procédures (Bruschi et Cendrero, 2005, 2009) et la pertinence des résultats.

Une stratégie de géoconservation structurée doit commencer par l'identification et la sélection des géosites, suivie d'une évaluation quantitative plus précise. La plupart des propositions méthodologiques citées ci-dessus ne présentent pas clairement comment les sites retenus ont été identifiés et sélectionnés. C'est dans ce contexte que se situe notre proposition méthodologique. Elle présente d'une part une procédure de sélection des géomorphosites effectifs entre différents éléments géomorphologiques ayant valeur potentielle de géomorphosites ; d'autre part, elle constitue un instrument de comparaison et de classement entre les géomorphosites sélectionnés. La méthode comprend deux étapes principales : l'inventaire et la quantification (fig. 1). L'étape d'inventaire est subdivisée en quatre sous-étapes : l'identification de géomorphosites potentiels ; leur évaluation qualitative ; la sélection des géomorphosites et leur caractérisation. L'étape de quantification inclut deux sous-étapes : l'évaluation numérique et l'analyse des résultats.

L'identification de géomorphosites potentiels est basée sur une série de critères (tab. 2), tels que la valeur scientifique,

la valeur esthétique, les relations entre les formes du relief et des éléments culturels ou écologiques. Les conditions de visibilité et la dimension physique des aspects géomorphologiques sont considérés pour la définition de trois types de géomorphosites selon l'échelle d'observation : les formes isolées, les sites surfaciques et les points panoramiques (fig. 2). Après l'identification des sites potentiels, ceux-ci sont soumis à une procédure d'évaluation afin de déterminer leur valeur intrinsèque, le potentiel d'utilisation et les nécessités de protection (tab. 3). La sélection des géomorphosites est basée sur résultats obtenus par l'évaluation qualitative (tab. 4). Des procédures directes et paramétriques (au sens de Bruschi et Cendrero, 2009) sont utilisées conjointement afin de procéder à la sélection des géomorphosites le plus objectivement possible, tout en bénéficiant de l'expertise géomorphologique de l'évaluateur. L'inventaire est complété par la caractérisation détaillée de chacun des géomorphosites sélectionnés (tab. 5), comprenant une description précise, une information cartographique, ainsi que des éléments sur le contexte géomorphologique, la valeur patrimoniale, l'utilisation et la gestion du site.

L'évaluation numérique reprend les critères utilisés dans l'étape précédente, en les distribuant en classes et en deux niveaux : des indicateurs principaux et secondaires (tab. 6). Des valeurs numériques sont attribuées aux critères et indicateurs afin d'obtenir un classement des géomorphosites permettant de les comparer. L'indicateur principal « valeur géomorphologique » (GmV) comprend les indicateurs secondaires « valeur scientifique » (ScV) et « valeur additionnelle » (AdV). L'indicateur principal « valeur de gestion » (MgV) intègre les indicateurs secondaires « valeur d'usage » (UsV) et « valeur de protection » (PrV). En ce qui concerne la pondération des résultats, la « valeur géomorphologique » et la « valeur de gestion » sont traitées de la même façon avec un maximum de dix points chacun.

Les critères inclus dans cette méthode (tab. 1) sont tirés d'une analyse de différentes méthodes existantes. Ils ont été considérés comme étant les plus représentatifs de la valeur intrinsèque (valeur géomorphologique) et de valeur de gestion des sites. L'étape de quantification prend en compte les objectifs possibles de l'évaluation, à savoir la protection ou la valorisation des géomorphosites. Les résultats de l'évaluation numérique sont reportés dans des tableaux permettant de comparer et classer les sites (tab. 7 et tab. 8). Enfin, des résultats numériques intégrés [« valeur totale » (TV) ou « ranking » (Rk)] sont créés ; s'ils sont intéressants afin d'obtenir un classement des géomorphosites, ils n'ont toutefois pas de signification particulière en termes de gestion. On devrait donc préférer une présentation et une analyse des résultats par indicateurs principaux et secondaires, plus utiles comme instruments d'aide aux décisions de gestion telles que des mesures de protection ou de publicité des géomorphosites.

Il est largement reconnu que l'élaboration de directives universelles pour l'évaluation des géomorphosites est très difficile, voire impossible, en raison de la diversité des environnements géomorphologiques, des différents objectifs de l'évaluation et surtout de la subjectivité inhérente à toutes les procédures d'évaluation. Toutefois, certaines spécificités de la méthode présentée ici peuvent être considérées comme des pro-

positions importantes pour toute évaluation de géomorphosites (Reynard, 2009) : l'évaluation vue comme une procédure intégrée qui comprend à la fois l'étude géomorphologique, la sélection des géomorphosites potentiels, l'évaluation numérique et les propositions pour la protection ou la promotion de géomorphosites ; l'organisation des critères par thèmes, concernant autant les valeurs intrinsèques (scientifique et additionnelles) que les valeurs de gestion (d'utilisation et de protection) ; l'analyse et la représentation des résultats non seulement de manière globale, mais aussi pour chacun des indicateurs retenus, afin d'obtenir les meilleurs instruments d'aide à la décision.

Introduction: geomorphosite assessment

Geomorphosites refer to the geomorphological assets of geological heritage, the term being a contraction of 'geomorphological sites' (Panizza, 2001). Geomorphological features have always been one of the most relevant issues in geological heritage and geoconservation movements and geomorphosites are a specific kind of geosite largely owing to their aesthetics, dynamics and size. Geomorphosites are understood to be landforms that have acquired a special value owing to human perception or exploitation (Panizza and Piacente, 1993). This value may vary, depending on the focus: scientific, ecological, cultural, aesthetic and/or economic (Reynard, 2005). According to the narrow definition of the term, a geomorphosite can be any part of the Earth's surface that is important for the knowledge of Earth, climate and life history (Grandgirard, 1997; Reynard, 2005). It has been well accepted that geomorphosites can only exist if, from a human perspective, they have one or more types of value. Scientific value must be seen as the fundamental kind of value for that recognition but other types of value like cultural, ecological or aesthetic are often considered in the selection and comparison of geomorphosites. Economic value refers mainly to the tourism potential of sites. One of the most important issues in geomorphosite research is the development of methodologies focused on the evaluation of the different types of value present in geomorphosites.

There are two main types of assessment. One is characterised by the selection of geomorphosites based on the expertise of assessors and qualitative procedures. This qualitative approach dates from the beginning of geomorphosite assessment during the 1960s (Watson and Slaymaker, 1966) and it is still used in different types of inventories. The quantitative approach is related to the need to rank the sites. It has been particularly developed since the 1990s in some scientific works (Grandgirard, 1997; Rivas *et al.*, 1997) and recently the number of methods has increased, testifying to the development of this subject within the scientific community. The definition of guidelines for coordinate geomorphosite assessments in various countries was the main objective of the working group 'Geomorphosites', which was created in 2001 under the aegis of the International Association of Geomorphologists (Reynard, 2009). Different national geomorphological contexts and objectives have not allowed the development of univer-

sal guidelines. Thus different groups of researchers have proposed various methodological procedures focused on geomorphosite specificities (Restrepo, 2004; Bonachea *et al.*, 2005; Bruschi and Cendrero, 2005; Coratza and Giusti, 2005; Pralong, 2005; Serrano and González-Trueba, 2005; Reynard *et al.*, 2007; Zouros, 2007). Although emphasis has been placed in these works on numerical assessment with a view to increasing the objectivity of results, the more subjective and often unsystematic process of geomorphosite selection does not seem to have received due attention.

According to V. Bruschi and A. Cendrero (2009) the qualitative and quantitative assessment approaches can be considered as direct and indirect (or parametric) methods, respectively. Direct assessments are usually led by experts supporting the identification and selection of the geomorphosites in the scope of inventories. These methods involve a high degree of subjectivity and the selection criteria are not always well explained. Parametric methods are more objective, using numerically quantified criteria and making it possible to obtain clear and replicable results. The methods proposed by the Geomorphosites Working Group are mainly connected with this parametric approach and aim at the quantitative assessment of previously selected geomorphosites. Nevertheless, they do not clarify exactly how the sites were identified and selected. We understand that an organised geoconservation strategy must start with the identification of potential geosites before continuing with a more accurate quantitative assessment. In that context and in the light of the Geomorphosites Working Group goals our methodological proposal looked for a holistic approach, integrating qualitative and quantitative procedures for the inventory and quantification of geomorphosites. In this paper, we aim to demonstrate the need for a comprehensive methodology that can function in the different stages and approaches of geomorphosite assessment. On the one hand it must be supportive of the selection of effective geomorphosites amongst several geomorphological assets and on the other hand must be an instrument for the comparison and ranking of these selected geomorphosites. Preliminary conclusions of our methodological procedure were presented during geomorphosite assessment in Montesinho Natural Park, Portugal (Pereira, 2006; Pereira *et al.*, 2007). In recent years the procedure has been implemented in some geomorphosite and geosite inventories and its application as well as the pertinence and/or absence of some assessment criteria are presented here. Of particular relevance is the compilation of the essential criteria on geomorphosite assessment for both approaches, qualitative and numerical. The various stages and specific procedures of the methodology are then described and discussed.

Criteria in geomorphosite assessment

The various assessment methodologies have the common goal of valuing the heritage features of landforms that are traded by different types of values. It is generally accepted that the value of geomorphosites can be scientific, ecological, cultural, aesthetic and/or economic (Reynard, 2005). Some

authors also consider that landforms have a functional value (Gray, 2004), as the support of environmental systems, both physical and biological. Almost all studies related to methodological proposals discuss geomorphosites' different types of values. It is generally accepted that scientific value is the essential value, some authors assessing only the scientific features of landforms (Grandgirard, 1997, 1999; Coratza and Giusti, 2005). Some works consider additional values like cultural, aesthetic and ecological, and other non-intrinsic values may be assessed for management purposes related to the potential for use and the need to protect geomorphosites. The choice of criteria for use in the assessment is therefore crucial. Most of the criteria proposed by different researchers reveal a consensus in the features to be valued (tab. 1). In the field of scientific value we stress criteria like rarity, representativeness, integrity and diversity of geomorphological features; other criteria for assessing this type of value are scientific knowledge and palaeogeographical value, as well as other geological features (Reynard, 2009). The additional value criteria are generally less precise depending on the sensitivity of the assessor but they are also essential for complete assessment (Pereira, 2006). In terms of management issues the most usual criteria are accessibility and visibility and, for instance, vulnerability to measure the need for protection. Other useful criteria for assessing the potential of use and need for protection include proximity of facilities and services, relationship with existing planning (Bruschi and Cendrero, 2005, 2009) or limits of acceptable change (Serrano and González-Trueba, 2005).

Scientific value criteria	Additional value criteria	Management criteria
rarity	cultural	accessibility
representativeness	ecological	visibility
integrity	aesthetics	vulnerability
diversity		
scientific knowledge		

Tab. 1 – Usual criteria in geomorphosite assessment methods.

Tab. 1 – Critères les plus utilisés dans les méthodes d'évaluation des géomorphosites.

Methodological procedure

The methodology was proposed by P. Pereira (2006) in the evaluation of the geomorphological heritage of Montesinho Natural Park (NE Portugal). It includes two main stages (inventory and quantification) and six sub-stages (fig. 1). During the inventory stage, geomorphosites are selected and characterised. During the quantification stage, the importance of sites is determined by numerical assessment of criteria, allowing the comparison of sites. The approach is based on the previous definition of three types of geomorphosites according to the observation scale: single places, areas and panoramic viewpoints (fig. 2). The scale is

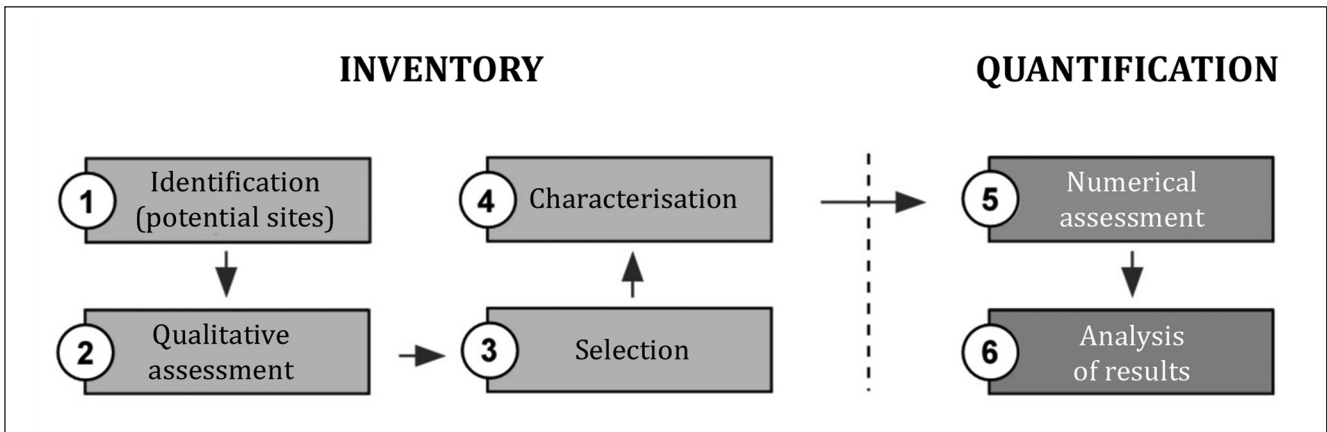


Fig. 1 – Proposed stages and sub-stages in geomorphosite assessment (after Pereira, 2006; Pereira et al., 2007).

Fig. 1 – Etapes et sous-étapes proposées pour l'évaluation des géomorphosites (d'après Pereira, 2006 ; Pereira et al., 2007).

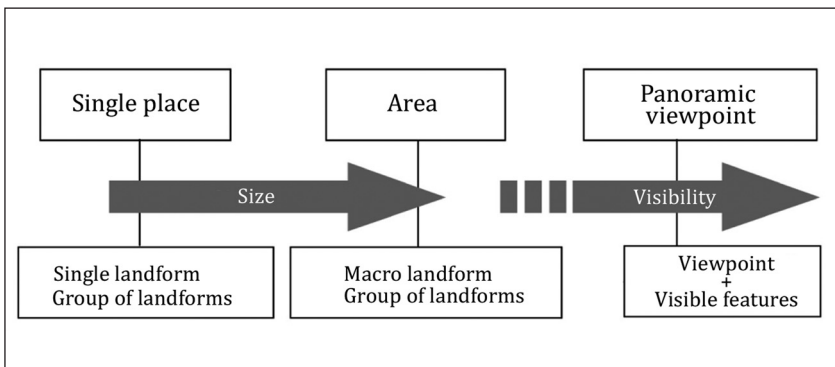


Fig. 2 – Typology of geomorphosites according to the observation scale (after Pereira, 2006).

Fig. 2 – Typologie des géomorphosites selon l'échelle d'observation (d'après Pereira, 2006).

- (i) scientific relevance recognised during the geomorphological survey of the area or by former scientific works;
- (ii) landform aesthetics and peculiarity, compared with other situations in the same or other areas;
- (iii) links between landforms and cultural elements such as archaeological features, population settlements, castles, agriculture, etc;
- (iv) links between landforms and ecological issues such as fauna and flora settlements.

Tab. 2 – Criteria for potential geomorphosites identification.

Tab. 2 – Critères pour l'identification des géomorphosites potentiels.

seen as an important issue owing to its relevance in assessment accuracy and it is also essential for future management actions. Single places are considered as isolated landforms or a small group of landforms (see Grandgirard, 1997, 1999 for the typology) that can be closely observed from a single point or a restricted area. Areas are constituted by one or more groups of landforms that can only be seen by the observer moving inside an area. Panoramic viewpoints are sites from where large landforms can be perceived. They include the local point, the landforms observed and can also include single points and areas. The basis for use of this geomorphosite assessment method is geomorphological knowledge of the area. For that it is crucial to collect informations on the regional setting, main landforms and processes, structural framework, climatic features, human activi-

CRITERIA		ASSESSMENT
Geomorphological intrinsic value (IV)	Scientific (Sc)	2 – low; 3 – medium; 4 – high; 5 – very high
	Other geomorphological values (Ogv) Ecological (Ec) Cultural (Cul) Aesthetic (Ae)	0 – nil; 1 - very low; 2 – low; 3 – medium; 4 – high; 5 – very high
Potential use (PU)	Accessibility (Ac) Visibility (Vi) Use of other natural or cultural values (Oth)	1 - very difficult; 2 - difficult; 3 - medium; 4 - easy/good; 5 - very easy/very good
Need for protection (NP)	Deterioration (De) Vulnerability (Vu)	1 – low; 2 – medium; 3 – high

Tab. 3 – Criteria used in the assessment of potential geomorphosites.

Tab. 3 – Critères utilisés pour l'évaluation des géomorphosites potentiels.

ties and geomorphological mapping, as well as other relevant natural and cultural aspects. From this information scientific, ecological, cultural and aesthetic characteristics of landforms may be identified.

Sub-stage 1: one of the essential aims of the inventory stage is the selection of landforms that can be defined as geomorphosites: potential geomorphosites. The identification process concentrates on a predefined range of criteria (tab. 2).

Sub-stage 2: after the identification of sites, use is made of a qualitative evaluation process to determine intrinsic value, potential use and required protection. Scientific, ecological, cultural and aesthetic features define the intrinsic value, with scores being given from 'nil' to 'very high' for ecological, cultural and aesthetic criteria (tab. 3). Regarding scientific value, scores vary from 'low' to 'very high' because the previously identified potential geomorphosites were recognised as having at least some scientific relevance (tab. 2). The potential use is defined on the basis of three main criteria: accessibility, visibility, and evidence of importance in other fields (e.g. biological, archaeological). The last aspect also takes current promotion and use of a site in other fields into account. Required protection includes assessment of levels of deterioration and vulnerability, with scores ranging from 'high' to 'low'. This aspect allows inclusion of past (deterioration) or future (vulnerability) threats in the assessment. Although the qualitative assessment may be brief, subjective and strongly influenced by the assessor's understanding of geomorphology and geoconservation, it is a fundamental

step in the overall assessment. The results therefore serve as a basis for the further sub-stages in the inventory phase.

Sub-stage 3: selection of geomorphosites is based on their rank performance during the previous qualitative assessment, with those sites that scored overall highest being selected for further characterisation (tab. 4). Potential geomorphosites with 'very high' scientific value are selected, independent of performance in other criteria (type I). Further, sites with 'high' geomorphological intrinsic value, 'high' potential use (accessibility, visibility, and use of other natural or cultural values) and low deterioration and vulnerability are selected independently (type II). Single places or areas that denote

Selection criteria	
I	Sc = 5
II	Sc = 4 or Sc = 3 and Ec ≥ 4 or Cul ≥ 4 or Ae ≥ 4; Ac ≥ 3 and Vi ≥ 4 or Oth ≥ 4; De ≤ 2 and Vu = 1
III	Single places and areas Sc = 4 or Sc = 3 and Ec ≥ 4 or Cul ≥ 4 or Ae ≥ 4; De ≤ 2 and Vu ≥ 2 (urgent need for protection)
IV	Panoramic viewpoints outside the study area Sc = 4 and Ec = 5 or Cul = 5 or Ae = 5; Ac ≥ 3 or Vi ≥ 4

Tab. 4 – Criteria used for geomorphosite selection.

Tab. 4 – Critères utilisés pour la sélection des géomorphosites.

GEOMORPHOSITE CHARACTERISATION	
GEOMORPHOLOGICAL DESCRIPTION, INTERPRETATION AND HERITAGE JUSTIFICATION	
Description	Regional and local geomorphological setting, and the main features observed.
Interpretation	Geomorphic processes, geomorphological evolution, and natural and cultural features related.
Heritage value	Justification of heritage value of the geomorphosite (high or very high intrinsic value).
CARTOGRAPHY	
Extract from the detailed geomorphological map (or geological if that does not exist) with the geomorphosite location. For panoramic viewpoints both the observation spot and the area seen from it must be located.	
ILLUSTRATION	
Photos with captions.	
USE AND MANAGEMENT	
Accessibility	Description of the access type (roads, trails, footpaths...), distances and existence of parking areas.
Visibility	Conditions for the geomorphosite user, existence of obstacles or vegetation.
Other kinds of value	Natural (flora, fauna, other geological assets) and cultural features with relevance for the site.
Present uses	Human activities and use as a natural or cultural site.
Conservation	Geomorphosite deterioration by natural or human causes.
Vulnerability	Possible geomorphosite deterioration by natural or human causes in the future mainly as the result of its use as a geomorphosite.
Legal status	Geomorphosite protection by legal instrument. For panoramic viewpoints both the observation spot and the area seen from it must be considered.
Supporting infra-structures	Existence of services and equipments for tourism use such as hotels, restaurants and information centres.
Necessary and possible actions	Proposition of initiatives for site prequalification and its use as geomorphosite.

Tab. 5 – Description of geomorphosite characterisation.

Tab. 5 – Éléments de caractérisation des géomorphosites.

GEOMORPHOLOGICAL VALUE (GmV; ScV + AdV; maximum 10)	
SCIENTIFIC VALUE (ScV; Ra + In + Rp + Dv + Ge + Kn + Rn; maximum 5.5)	
Ra	Rarity inside the area (maximum 1)
In	Integrity (maximum 1)
Rp	Representative of geomorphological processes and pedagogical interest (maximum 1)
Dv	Number of interesting geomorphological features (diversity) (maximum 1)
Ge	Other geological features with heritage value (maximum 0.5)
Kn	Scientific knowledge of geomorphological issues (maximum 0.5)
Rn	Rarity at national level (maximum 0.5)
ADDITIONAL VALUE (AdV; Cult + Aest + Ecol; maximum 4.5)	
Cul	Cultural value (maximum 1.5)
Ae	Aesthetic value (maximum 1.5)
Ec	Ecological value (maximum 1.5)
MANAGEMENT VALUE (MgV; UsV + PrV) (maximum 10)	
USE VALUE (UsV; Ac+Vi+Gu+Ou+Lp+Eq; maximum 7.0)	
Ac	Accessibility (maximum 1.5)
Vi	Visibility (maximum 1.5)
Gu	Present use of the geomorphological interest (maximum 1)
Ou	Present use of other natural and cultural interests (maximum 1)
Lp	Legal protection and use limitations (maximum 1)
Eq	Equipments and support services (maximum 1)
PROTECTION VALUE (PrV; In + Vu; maximum 3.0)	
In	Integrity (maximum 1)
Vu	Vulnerability of use as geomorphosite (maximum 2)

Tab. 6 – Indicators and criteria used in geomorphosite numerical assessment.

Tab. 6 – Indicateurs et critères utilisés dans l'évaluation numérique des géomorphosites.

	ScV	AdV	GmV	UsV	PrV	MgV	TV
A	4.83	1.88	6.71	3.55	2.25	5.80	12.51
B	3.58	2.62	6.20	5.12	2.75	7.87	14.07
C	3.75	3.62	7.37	3.27	1.75	5.02	12.39
D	2.94	1.37	4.31	3.11	2.50	5.61	9.92
E	4.58	2.58	7.16	4.07	2.75	6.82	13.98

Tab. 7 – Example of quantified results using hypothetical geomorphosites A, B, C, D, and E.

Tab. 7 – Exemple de résultats quantifiés impliquant les géomorphosites hypothétiques A, B, C, D et E.

	ScV	AdV	GmV	UsV	PrV	MgV	TV	Rk
1st	A (4.83)	C (3.62)	C (7.37)	B (5.12)	E (2.75)	B (7.87)	B (14.07)	E (14)
2nd	E (4.58)	B (2.62)	E (7.16)	E (4.07)	B (2.75)	E (6.82)	E (13.98)	B (15)
3rd	C (3.75)	E (2.58)	A (6.71)	A (3.55)	D (2.50)	A (5.80)	A (12.51)	A (21)
4th	B (3.58)	A (1.88)	B (6.20)	C (3.27)	A (2.25)	D (5.61)	C (12.39)	C (23)
5th	D (2.94)	D (1.37)	D (4.31)	D (3.11)	C (1.75)	C (5.02)	D (9.92)	D (32)

Tab. 8 – Example of ranking results using hypothetical geomorphosites A, B, C, D, and E.

Tab. 8 – Exemple de résultats de classement impliquant les géomorphosites hypothétiques A, B, C, D et E.

need for protection are also selected if they have 'high' scientific value or 'high' or 'very high' score in one or more of the other geomorphological values (type III). Panoramic viewpoints located outside of the study area are selected if they have at least a 'high' scientific value and furthermore a 'very high' ecological, cultural or aesthetical value and good conditions of accessibility and visibility (type IV).

Sub-stage 4: the process involved in the compilation of the inventory is considered complete with the detailed description of each of the selected geomorphosites. These descriptions are expected to include cartographic data as well as information on geomorphology, 'heritage value', and use and management, where applicable (tab. 5). The latter category would thus deal with accessibility, visibility, present uses, conservation, vulnerability, legal status and supporting infrastructures. The information collected here is expected to support the next assessment sub-stage and is likely to be of benefit to future management initiatives.

The quantification stage involves two sub-stages: numerical assessment and geomorphosite ranking. It succeeds the geomorphosite characterisation and builds on the data compiled during that sub-stage. The results allow comparison of the inventoried geomorphosites.

Sub-stage 5: the numerical assessment uses the criteria introduced in the previous stage, but divides them up into different classes in order to create two levels: principal and secondary indicators. The division of criteria takes into account the possible objectives of the assessment, i.e. the protection or promotion of geomorphosites. For this reason, the principal indicator 'geomorphological value' includes the secondary indicators 'scientific value' and 'additional values'. 'Management value', as second principal indicator, integrates the secondary indicators 'use value' and 'protection value'. With regard to the weighting of results, 'geomorphological value' and 'management value' are treated the same with a maximum of ten points each (tab. 6). The sum of all indicators determines the total value of the geomorphosite.

Sub-stage 6: the results of the numerical assessment are recorded in a quantification table (example in tab. 7). All criteria are assessed for each of the geomorphosites. As all data are recorded on the same table, a direct comparison of site ranks is possible (example in tab. 8). The sum of all principal and secondary indicators is expressed as total value (TV) and the sum of rank positions

according to indicator (primary and secondary) is taken into account in final ranking (Rk).

Consequently, the sites with lowest final ranking scores may be considered to be the most valuable geomorphosites in the area being assessed. The aim of emphasising rank averages in geomorphosite assessment is to produce relative value or homogeneity of criteria results. Thus, geomorphosites that score well over the full spectrum of indicators will also be amongst the best placed in the final ranking. The method can, however, engender differences from Total Value results (tab. 8, geomorphosites B and E).

Discussion: assessment to support management

The proposed methodological sequence aims to use both types of assessment procedures defined by V. Bruschi and A. Cendrero (2005, 2009). It uses direct and parametric methods benefiting from the assessor's geomorphological knowledge for the geomorphosite selection. It also uses numbers and clear criteria and indicators for ranking and comparison of geomorphosites. Therefore, it groups in the same process the two main assessment stages: inventory and quantification. The main goal was to include in the procedure different assessment tasks from the identification of potential geomorphosites to their comparison and analysis for management decisions. It is seen as important that assessment would be better in both qualitative and quantitative approaches if done by geomorphology and/or geoconservation experts acquainted with the study area.

The definition of types of geomorphosites according to their scale of observation is an essential issue, in order to help both assessment and management procedures. We also emphasise that this method can be partially used depending on the pre-existence of inventories and assessment objectives. Therefore the assessment can start with the numerical approach without the previous sub-stages procedures if there already exists a geomorphosite inventory. If the aim of the assessment is to identify and make a list of the geomorphosites of a certain area, then the first stage (inventory) could be sufficient.

In fact, one seminal work on geomorphological heritage assessment recommended three critical questions to inform assessment: What? Why? How? (Grandgirard, 1999). 'What?' refers to scope in terms of area size and geomorphological environment. 'Why?' refers to the definition of one or more main objectives, such as identification, inventorying and site protection or promotion. 'How?' refers to the choice of assessment method. This choice should also take scope and objectives into consideration. Furthermore, a holistic approach to geomorphosite assessment takes geomorphosite management into account (Pereira *et al.*, 2007). Thus, assessment should not only involve classification of sites, but offer suggestions for their protection, promotion and monitoring. The numerical assessment must be seen as part of a larger procedure that includes: the geomorphological study of the area; the selection of geomorphosites based on the results of that geomorphological study; the numerical assessment; the

proposals for protection or promotion of geomorphosites (Pereira, 2006; Pereira *et al.*, 2007; Reynard, 2009).

In that sense, the reading of the results by different indicators is felt to be particularly useful for supporting site management decisions like measures for the protection, education and promotion of geomorphosites. As also argued by Reynard (2009), special attention must be given to the presentation and analysis of results. Integrated numerical results may be interesting for obtaining a mean geomorphosite ranking but have no special meaning in terms of management. Indicators such as Total Value (TV) or Ranking Value (Rk) may not make a special contribution to protection or promotion decisions. Above all the analysis must be focused on each of the subjects of the assessment. One would prefer presentation and analysis of results by indicators (scientific, additional, use and protection values) in order to support management decisions better. Exemplifying this, geomorphosite C (tab. 7 and tab. 8) obtained a high score in Geomorphological Value (GmV) but a very low score in Management Value (MgV) and consequently low score in Total Value (TV) and Ranking Value (Rk). Because of this partial analysis, it could be excluded from eventual promotion initiatives in order to be protected.

The criteria included in this method are the result of the analysis of other methodological proposals concerning the quantitative assessment of geomorphosites. These criteria were considered as most representative of the heritage value of landforms for each of the proposed indicators. One should remember that even the choice of criteria brings some subjectivity to the process, confirmed by the existence of different criteria in each of the analysed methods. Nevertheless, independently of the criteria used in the assessment it is important how they are organised and divided in intrinsic value (scientific and additional) and management value (potential use and need for protection), easing the assessment and supporting management. Finally, we should state that following this arrangement by main assessment indicators/subjects the criteria are the same, independently of the stage of the assessment (inventory or quantification).

Conclusion

The establishment of a universal methodology for geomorphosite assessment was one of the main goals of the international task force working over the last few years in this area. The method here proposed was developed as part of that work, being applied in recent years to different types of geomorphological environments. With modified criteria the method structure is being applied in geosite assessments, even in the ongoing inventory of Portuguese geological heritage. One should recognise that this methodological proposal is not intended to establish universal methodological guidelines, despite contributing to the discussion on one of the main subjects of geomorphological heritage. In fact, it is well accepted that the development of such universal guidelines is very difficult owing to the diversity of geomorphological environments, the different assessment purposes and, mainly, the inherent subjectivity in all the assessment

procedures. Nevertheless, the specificities of this method were considered as important guidelines for geomorphosite assessment (Reynard, 2009), namely: the recognition of geomorphosite assessment as a broad procedure that includes the geomorphological study of the area, the selection of geomorphosites based on the results of that geomorphological study, the numerical assessment and the proposals for protection or promotion of geomorphosites; the organisation of criteria by subject, concerning intrinsic values (scientific and additional) and management values (potential for use, threats and need for protection); the representation and analysis of results by each of these indicators, in order to support accurate management decisions.

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References

- Bonachea J., Bruschi V., Remondo J., González-Díez A., Salas L., Bertens J., Cendrero A., Otero C., Giusti C., Fabbri A., González-Lastra J., Aramburu J. (2005)** – An approach for quantifying geomorphological impacts for EIA of transportation infrastructures: a case study in northern Spain. *Geomorphology* 66, 95-117.
- Bruschi V., Cendrero A. (2005)** – Geosite evaluation: can we measure intangible values? *Il Quaternario* 18-1, 293-306.
- Bruschi V., Cendrero A. (2009)** – Direct and parametric methods for the assessment of geosites and geomorphosites. In Reynard E., Coratza P., Regolini-Bissig G. (Eds.): *Geomorphosites*. Verlag Friedrich Pfeil, Munchen, 73-88.
- Coratza P., Giusti C. (2005)** – Methodological proposal for the assessment of the scientific quality of geomorphosites. *Il Quaternario* 18-1, 307-313.
- Grandgirard V. (1997)** – *Géomorphologie, protection de la nature et gestion du paysage*. Thèse de doctorat en géographie, université de Fribourg, 210 p.
- Grandgirard V. (1999)** – L'évaluation des géotopes. *Geologica Insubrica* 4-1, 59-66.
- Gray M. (2004)** – *Geodiversity: Valuing and conserving abiotic nature*. Wiley, Peterborough, 434 p.
- Panizza M. (2001)** – Geomorphosites. Concepts, methods and examples of geomorphological survey. *Chinese Science Bulletin* 46, 4-6.
- Panizza M., Piacente S. (1993)** – Geomorphological assets evaluation. *Zeitschrift für Geomorphologie*, Suppl. Bd. 87, 13-18.
- Pereira P. (2006)** – *Património geomorfológico: conceptualização, avaliação e divulgação. Aplicação ao Parque Natural de Montesinho*. PhD thesis, Departamento de Ciências da Terra, universidade do Minho, 370 p.
- Pereira P., Pereira D.I., Alves M.I.C. (2007)** – Geomorphosite assessment in Montesinho Natural Park (Portugal). *Geographica Helvetica* 62, 159-168.
- Pralong J.-P. (2005)** – A method for assessing tourist potential and use of geomorphological sites. *Géomorphologie: relief, processus, environnement* 3, 189-196.
- Restrepo C. (2004)** – Patrimonio geomorfológico de la región central antioqueña (Colombia). In Mata-Perelló J. (Ed.): *Defensa del patrimonio y desarrollo regional*. Sociedad Española para la Defensa del Patrimonio Geológico y Minero, Madrid, 211-219.
- Reynard E. (2005)** – Géomorphosites et paysages. *Géomorphologie: relief, processus, environnement* 3, 181-188.
- Reynard E. (2009)** – The assessment of geomorphosites. In Reynard E., Coratza P., Regolini-Bissig G. (Eds.): *Geomorphosites*. Verlag Friedrich Pfeil, Munchen, 63-72.
- Reynard E., Fontana G., Kozlik L., Scapozza C. (2007)** – A method for assessing 'scientific' and 'additional values' of geomorphosites. *Geographica Helvetica* 62, 148-158.
- Rivas V., Rix K., Frances E., Cendrero A., Brunsten D. (1997)** – Geomorphological indicators for environmental impact assessment: consumable and non-consumable geomorphological resources. *Geomorphology* 18, 169-182.
- Serrano E., Gonzalez-Trueba J. (2005)** – Assessment of geomorphosites in natural protected areas: the Picos de Europa National Park (Spain). *Géomorphologie: relief, processus, environnement* 3, 197-208.
- Watson E., Slaymaker O. (1966)** – *Mid-Wales, a survey of geomorphological sites*. Department of Geography, University College of Wales, Aberystwyth, 92 p.
- Zouros N. (2007)** – Geomorphosite assessment and management in protected areas of Greece. Case study of the Lesvos island – coastal geomorphosites. *Geographica Helvetica* 62, 169-180.

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