A method for assessing the scientific and additional values of geomorphosites

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Abstract
During the last decade, several methods have been developed in order to reduce subjectivity – by the use of transparent assessment criteria – within the processes of selection of geomorphosites. Most of these methods propose criteria (integrity, rarity, representativeness, palaeogeographical importance) aimed at the evaluation of the scientific value of sites. It has been demonstrated that the global quality of geomorphosites is also based on several additional values (ecological, cultural, aesthetic, economic). This paper proposes a new assessment method that integrates the additional values in the evaluation also. The method is described and two applications – an inventory of the geomorphosites within the project of National Park of Adula (Ticino) and the evaluation of the geocultural heritage of the Trient area (Valais) –, are presented.

Résumé
Différentes méthodes ont été développées durant la dernière décennie en vue de réduire la subjectivité – en utilisant des critères objectifs – lors des processus d’évaluation des géomorphosites. La plupart de ces méthodes sont basées sur l’utilisation de critères (intégrité, rareté, représentativité, valeur paléogéographique) qui concernent la valeur scientifique des sites. La qualité globale des sites dépend toutefois aussi de différentes valeurs dites additionnelles (écologique, culturelle, esthétique, économique). Cet article propose une nouvelle méthode d’évaluation qui intègre les valeurs additionnelles dans le processus d’évaluation. La méthode est décrite et deux exemples – un inventaire de géomorphosites réalisé dans le cadre du projet de Parc national de l’Adula (Tessin) et l’évaluation du patrimoine géoculturel de la vallée du Trient (Valais) – sont présentés.

Zusammenfassung
Keywords
Geomorphosites, geoheritage, assessment, inventories.

Mots-clés
Géomorphosites, patrimoine géomorphologique, évaluation, inventaires.

Stichwörter
Geomorphologische Geotope, geomorphologisches Erbe, Bewertung, Inventare.

1 Introduction

During the last two decades, several attempts have been made in order to evaluate the quality of the geomorphological heritage in various contexts like environmental impact assessment (Rivas et al. 1997, Coratza & Giusti 2005), inventories of natural heritage sites (Serrano & González Trueba 2005), tourist promotion (Pralong 2005) or management of nature parks (Pereira et al., this volume). In order to reduce subjectivity (Bruschi & Cendrero 2005), numerous more or less quantitative assessment methods have been developed (e.g. Grandgirard 1997, Coratza & Giusti 2005, Serrano & González Trueba 2005, Pereira et al., this volume). The various methods are based on several assessment criteria; three of them are recurrent, that is rarity, representativeness and integrity (Grandgirard 1999), and others – e.g. the ecological value, the palaeogeographic importance, the educative value, etc. – are dependent of the context of the assessment and on the aim of the research. They depend also on the definition of geomorphological heritage.

The geomorphological heritage is constituted of sites of interest called geomorphosites (Panizza 2001). Different terms have been used in the literature (Reynard 2004), like geomorphological assets (Panizza & Piacente 1993), geomorphological goods (Carton et al. 1994), geomorphological sites (Hooke 1994), geomorphological geotopes (Grandgirard 1997), sites of geomorphological interest (Rivas et al. 1997), and finally geomorphosites (Panizza 2001). In this paper, we use the term “geomorphosites” for naming sites of particular interest in terms of geomorphological heritage. Study of the literature shows that the various terms cover a relatively broad definition (Reynard 2005a): for some scholars (e.g. Grandgirard 1997), geomorphosites are sites of particular importance for the knowledge of Earth history and for the reconstruction of history of life, climate and Earth; for others (e.g. Panizza & Piacente 1993, Panizza 2001), the importance of geomorphosites is not only related on their scientific value – that is their importance for knowledge of Earth history –, but also on other characteristics and links with ecology, economy or culture (Panizza & Piacente 2003). The two definitions are not exclusive and their use depends on the objective of the research (Reynard 2005a): for inventories of sites to be protected, the restrictive definition should be used, because the selected sites and areas are those of particular importance for the knowledge of Earth history; on the other hand, within the context of geotourism or integrated cultural landscape management, the broad definition may be used in order to facilitate the analysis of relationships with other sectors of culture or science.

The coexistence of different types of definitions and various terms covering more or less the same concept does not facilitate the development of assessment methods. Actually, as was pointed by Grandgirard (1999), the choice of the assessment method and criteria depends
on the objectives of the research. It depends also on the definition – broad or narrow – of geomorphosites that is used. In order to clarify the debate concerning the value of sites, we have proposed to distinguish two levels of values (REYNAUD 2005a): the central one – that is the scientific value –, and additional values (cultural, economic, aesthetic and ecological). In this paper, we propose a quite simple assessment method that allows us to assess the two levels of values. After presenting the different parts of the assessment method, we develop two examples of evaluation realised in the Swiss Alps.

2 The assessment method

2.1 Evaluation card

As done some 15 years ago for geomorphological mapping (SCHOENEICH 1993), the Institute of Geography of the University of Lausanne has developed the proposed method with the objective to be used by students. For this reason, it is a quite simple method that does not require a too long or complex assessment procedure, as some of the existing methods do (PRALONG 2005; PEREIRA et al., this volume). The evaluation is based on a card (REYNAUD 2006) divided into six parts (Table 1). For the third and fourth criteria (central and additional values), the assessment is expressed by a text and by a numerical score, going from nil (0) to very high (1).

<table>
<thead>
<tr>
<th>Parts and criteria</th>
<th>Sub-criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 General data</td>
<td>Code, location, type, property, etc.</td>
</tr>
<tr>
<td>2 Descriptive data</td>
<td>2a Description</td>
</tr>
<tr>
<td></td>
<td>2b Morphogenesis</td>
</tr>
<tr>
<td>3 Scientific value</td>
<td></td>
</tr>
<tr>
<td>4 Additional values</td>
<td>4a Ecological value</td>
</tr>
<tr>
<td></td>
<td>4b Aesthetic value</td>
</tr>
<tr>
<td></td>
<td>4c Cultural value</td>
</tr>
<tr>
<td></td>
<td>4d Economic value</td>
</tr>
<tr>
<td>5 Synthesis</td>
<td>5a Global value</td>
</tr>
<tr>
<td></td>
<td>5b Educational value</td>
</tr>
<tr>
<td></td>
<td>5c Threats</td>
</tr>
<tr>
<td></td>
<td>5d Management measures</td>
</tr>
<tr>
<td>6 References</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parts of the evaluation and criteria used for the assessment.
Tableau 1 : Différentes parties de l’évaluation et critères utilisés.
Tabelle 1 : Verschiedene Abschnitte der Bewertung und deren Kriterien.

2.2 General data

The first part of the card contains general data (Table 2). This is expressed in a numerical form (e.g. coordinates, altitudes, size) or by using a code (e.g. identification, type, property). The identification code is divided into three parts (region, process and number), each of them with three elements: e.g. VALgla001 for a moraine (glacial form) assessed within the inventory of geomorphosites of the Canton of Valais. The characteristics concerning the property rights (private, association, public and common-property) are particularly important for the management of sites (REYNAUD 2005b): sites located on privately owned terrains are generally more difficult to protect (or promote) than objects owned by the State or by corporations. The property data may be difficult to obtain. Actually, the geomorphosite’s
owner is not always the same as the terrain owners. That is, for example, the case of erratic boulders that were acquired by scientific associations in the 19th century. For large geomorphosites – what we have called “geomorphological landscapes”, Reynard, 2005a –, the owners may be numerous and of different kinds. The use of numerical data and codes is particularly interesting if the database is created in a Geographic Information System (GIS), because spatial analysis (selection, classification, etc.) may be carried out.

<table>
<thead>
<tr>
<th>Identification code</th>
<th>Name</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPITAL LETTERS FOR THE REGION; letters for the process*, numerical code for the site. Each code has three characters (see text).</td>
<td>Name of the landform or very simplified description of the geomorphosite (e.g. moraine, group of sinkholes, glacier forefield, meander, etc.)</td>
<td>As precise as possible e.g. Mont d'Or N, Le They, Finhaut, VS.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coordinates</th>
<th>Minimum Altitude</th>
<th>Maximum Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swiss national system or other national systems.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCT : punctiform (e.g. sinkhole)</td>
<td>Punctiform : no indication or width [m] (e.g. sinkhole) or volume [m³] (e.g. erratic boulder)</td>
<td>Property of the terrain or the object: PRI: private ASS: association PUB: public COM: common</td>
</tr>
<tr>
<td>LIN : linear (e.g. river)</td>
<td>Linear: length [m]</td>
<td></td>
</tr>
<tr>
<td>AER : areal (e.g. glacier forefield)</td>
<td>Areal: surface [m²]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Map</th>
<th>Pictures</th>
<th>Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale: 1:25'000 or 1:10'000, with precise localisation or perimeter</td>
<td>Good quality, 300 dpi</td>
<td>e.g. diagram, simplified map, paleogeographic sketch, etc.</td>
</tr>
</tbody>
</table>

Table 2: General data. * Codes used for the processes are the following: STR= structural landforms, FLU= fluvial, KAR= karstic, GLA: glacial, PER= periglacial, ORG= organic, EOL= aeolian, LIT= coastal, ANT= anthropic, etc.

Tableau 2 : Données générales. * Les codes concernant les processus sont les suivants : STR= formes structurales, FLU= fluvial, KAR= karstique, GLA: glaciaire, PER= périglaciaire, ORG= organique, EOL= éolien, LIT= littoral, ANT= anthropique, etc.


2.3 Descriptive data

This part is divided into two steps: description and morphogenesis. The description is based on observations made by the author during the fieldwork, on document analyses (maps, air photographs) and bibliographical information (previous studies). The description concerns not only the geomorphological features, but also other qualities like archaeological findings, human infrastructures, biotopes, etc. For the morphogenesis analysis, the accent is put on the processes responsible for the landform genesis and development, on temporal information (datation), and on the activity of the landform. In a second phase, the human transformations – if existing – are also analysed.

2.4 Scientific value

This part of the evaluation aims at assessing the mere scientific value of the site, based on the restrictive definition of geomorphosites proposed by GRANDGIRARD (1995, 1997, 1999). The criteria are those proposed by GRANDGIRARD (1999) (Table 3) – rareness, representativeness, integrity and palaeogeographic value. The last one is important, because it
allows us to evaluate the importance of the site for the knowledge of Earth and climate history.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrity</td>
<td>State of conservation of the site.  Bad conservation may be due to natural factors (e.g. erosion) or human factors.</td>
</tr>
<tr>
<td>Representativeness</td>
<td>Concerns the site’s exemplarity. Used with respect to a reference space (e.g. region, commune, country). All the selected sites should cover the main processes, active or relict, in the study area.</td>
</tr>
<tr>
<td>Rareness</td>
<td>Concerns the rarity of the site with respect to a reference space (e.g. region, commune, country). The criterion serves to illustrate the exceptional landforms in the area.</td>
</tr>
<tr>
<td>Paleogeographical value</td>
<td>Importance of the site for the Earth or climate history (e.g. reference site for a glacial stage).</td>
</tr>
</tbody>
</table>

Table 3: Criteria used for the assessment of the scientific value.
Tableau 3 : Critères utilisés dans l’évaluation de la valeur scientifique.
Tabelle 3 : Für die Ermittlung des wissenschaftlichen Wertes benutzte Kriterien.

2.5 Additional values

The additional values are assessed in four categories: ecological, aesthetic, cultural and economic value (Table 4). It is difficult for a geomorphologist to evaluate “technical” components covering a large spectrum of disciplines (biology, history, economy). This part of the evaluation is therefore based essentially on bibliographical data and simple criteria. The aim is not to give an exhaustive analysis of the site in terms of economy, ecology, arts or history, but to show the links existing between geomorphology and other aspects of nature or culture.

The “ecological impact” criterion (EcI) measures the importance of the geomorphosite for the development of a particular ecosystem or the presence of a particular fauna and vegetation. A moraine that allows the presence of a marsh with orchids will, for example, be given a high score. The assessment is based on the existing literature or discussions with specialists. Concerning the “protected site” criterion (PS), we consider that if a site is protected (e.g. national inventory, cantonal or local protection) for ecological reasons (e.g. marshes, alluvial zones), it has a particular ecological value. Several Swiss inventories of natural values – e.g. marsh landscapes, proglacial margins – are, moreover, based on biological and geomorphological selection criteria. The “ecological value” corresponds to the arithmetical mean of the “ecological impact” and “protected site” criteria: ECOL = (EcI + PS)/2.

The assessment of the aesthetic value is very subjective. We propose two simple criteria. The first one (“view points”) takes into account the observation possibilities. A site covered by a forest or very difficult to access has a low score, whereas a site visible by several viewpoints has a high score. Literature on landscape perception (see for example GRANDGIRARD (1997) or DROZ & MIÉVILLE-OTT (2005) for a review) shows that contrasted landscapes, landscapes with a vertical development or landscapes with individual elements
that structure the space are generally considered as the “nicest”. The sites with colour contrasts (e.g. contrasts due to lithological changes), high vertical development (e.g. peaks) or that structure the space (e.g. morainic arcuate ridge that close a valley, braided rivers) will receive a largest score than monotone reliefs (e.g. alluvial plain, large plateau). The “aesthetic value” corresponds to the arithmetical mean of two proposed criteria: 
\[ \text{AEST} = \frac{(VP + STR)}{2} \]

The “cultural value” criterion is the more heterogeneous one. We have divided it into four independent sub-criteria. The “religious importance” concerns sites that have a religious, mythological or mystic value. Numerous erratic boulders have, for example, been used as religious or mystic sites (LUGON et al., in press). The “historical importance” covers the history in a broad sense, that is archaeology, prehistory and history, and is assessed by the presence of vestiges. Not only the role of the object for the political history (e.g. the presence of castles on glacial locks), but also its importance for tourism history (e.g. waterfalls in Switzerland that were tourist attractions in the 18th century) or science history is concerned by this criterion (e.g. the Pierre Bergère erratic boulder in Salvan (Valais), that was used by Guglielmo Marconi for the first wireless experiments in the world; see REYNARD et al., in press). The “artistic and literature importance” concerns the presence of the site in artistic realisations (paintings, sculptures, etc.) and in books and poems. Finally, the “geohistorical importance” is related to the role of particular sites in the development of geosciences (LUGON & REYNARD 2003). The experience has shown that geomorphosites have generally only one or two of the cultural sub-values; for this reason, for this criteria, we do not calculate the mean of the different sub-values, but we take into account the highest score obtained on one of the four sub-criteria.

The “economic value” is obtained by a qualitative – and, if possible, quantitative – assessment (e.g. number of visitors, benefits) of the products generated by the geomorphosite. Only the incomes produced by the presence of the geomorphosite are evaluated (e.g. number of entrances in a tourist site), but not the potential of use and the indirect incomes related to the presence of the site (e.g. the presence of a hotel in the surroundings of a tourist cave).

<table>
<thead>
<tr>
<th>Value</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological value (ECOL)</td>
<td>a. ecological impact (EcI)</td>
</tr>
<tr>
<td></td>
<td>b. protected site (PS)</td>
</tr>
<tr>
<td>Aesthetic value (AEST)</td>
<td>a. view points (VP)</td>
</tr>
<tr>
<td></td>
<td>b. Contrasts, vertical development and space structuration (STR)</td>
</tr>
<tr>
<td>Cultural value (CULT)</td>
<td>a. religious importance (REL)</td>
</tr>
<tr>
<td></td>
<td>b. historical importance (HIS)</td>
</tr>
<tr>
<td></td>
<td>c. artistic and literature importance (ART)</td>
</tr>
<tr>
<td></td>
<td>d. geohistorical importance (GEO)</td>
</tr>
<tr>
<td>Economic value (ECON)</td>
<td>Economic products (ECO)</td>
</tr>
</tbody>
</table>

Table 4: Additional values.
Tableau 4 : Valeurs additionnelles.
Tabelle 4 : Zusätzliche Werte.

2.6 Synthesis

The fifth part makes a synthesis of the assessment of the central and additional values (Table 5). The synthesis is expressed by a sentence that summarizes the scientific and the four
additional values. Two scores give the numerical evaluation: the scientific score and the mean of the four additional values. We do not express the global value by a unique score integrating the five values, in order to distinguish the importance of the scientific – central – value with respect to the additional values. Second the objective of the evaluation (see the Trient case study below), one can decide to assess only one or two additional values.

In the second section, the importance of the site for education is expressed by a sentence. A geomorphosite with high educational value is a place where the landforms are particularly visible in the landscape. Places where the processes are particularly active may also have an important educative value.

The synthesis contains also a chapter regarding the threats. All the human and natural threats and both the existing and potential threats are listed. Actually, a geomorphosite may be disturbed, and even destroyed, by both human impacts and natural processes (REYNARD 2004). Human impacts are related to infrastructure buildings, urbanisation, territorial planning, agriculture, forestry, tourism and vandalism. Natural processes are related to climate change (destruction of a cryospheric geomorphosite), biological processes (weathering), geomorphological and geological processes or hydrological phenomena.

From the global assessment and the listing of threats, management measures are then proposed. They are divided into two groups covering the geoheritage issues: protection and promotion. Protection measures may be both active (e.g. building of protection infrastructures, fencing) and “passive” (territorial planning measures, institutional – public policies, property rights – measures) (REYNARD 2005b). The promotion aims at the development of tourist or educative goods and services (geotourism, geodidactics).

<table>
<thead>
<tr>
<th>Parts</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global value</td>
<td>The global value is expressed by a sentence that summarizes the central and four additional values.</td>
</tr>
<tr>
<td>Educational value</td>
<td>Importance of the site for education (school, universities).</td>
</tr>
<tr>
<td>Threats</td>
<td>Natural and human existing and potential threats.</td>
</tr>
<tr>
<td>Management measures</td>
<td>Proposed measures in order to protect and/or promote the site</td>
</tr>
</tbody>
</table>

Table 5: Synthesis of the assessment.
Tableau 5 : Synthèse de l’évaluation.
Tabelle 5 : Zusammenfassung der Bewertung.

3 Case studies

3.1 The inventory of geomorphosites in the Blenio valley and Lucomagno area

The first example concerns a research carried out in the Blenio valley and Lucomagno area in Northern Ticino (Switzerland). The objective was to contribute to the project of the National Park of Adula with an inventory of the geomorphological heritage of the area. The geomorphosites were assessed with the method presented above (table 6 and 7) and represented on a map (fig. 1).

For each area (Blenio valley and Lucomagno area), two maps were created. The first one (fig. 1, above) represents the sites in relation to their morphogeny (process). In the second one
(fig. 1, below), the central and additional values are represented. The scientific value is given by proportional circles and the dominant additional value is represented by specific graphics.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Code</th>
<th>Name</th>
<th>Integrity</th>
<th>Represent.</th>
<th>Rarity</th>
<th>Paleaogeogr. value</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BLEkar003</td>
<td>Karstic area</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>BLEkar004</td>
<td>Fluvial/karstic area</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>BLEper003</td>
<td>Retief rock glacier</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>BLEgla002</td>
<td>Erratic boulder</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>5</td>
<td>BLEgla004</td>
<td>Ice cave</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>6</td>
<td>BLEkar001</td>
<td>Karstic area</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.88</td>
</tr>
<tr>
<td>7</td>
<td>BLEgla003</td>
<td>Granite/diorite glacial lock</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
<td>8</td>
<td>BLEper001</td>
<td>Active rock glacier</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
<td>9</td>
<td>BLEper002</td>
<td>Inactive rock glacier</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
<td>10</td>
<td>BLEkar005</td>
<td>Residual landform</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.25</td>
<td>0.81</td>
</tr>
<tr>
<td>11</td>
<td>BLEorg001</td>
<td>Marsh area</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>12</td>
<td>BLEgla006</td>
<td>Postglacial gorge</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.50</td>
<td>0.81</td>
</tr>
<tr>
<td>13</td>
<td>BLEgla005</td>
<td>Roches moutonnées</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.50</td>
<td>0.81</td>
</tr>
<tr>
<td>14</td>
<td>BLEflu001</td>
<td>Alluvial zone</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>15</td>
<td>BLEgpa001</td>
<td>Postglacial rockfall</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td>16</td>
<td>BLEgla001</td>
<td>Glacial lake</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.00</td>
<td>0.69</td>
</tr>
<tr>
<td>17</td>
<td>BLEkar002</td>
<td>Sinkhole alignment</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.25</td>
<td>0.69</td>
</tr>
<tr>
<td>18</td>
<td>BLEant001</td>
<td>Gold mine</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.00</td>
<td>0.69</td>
</tr>
<tr>
<td>19</td>
<td>BLEant002</td>
<td>Soapstone quarry</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.00</td>
<td>0.63</td>
</tr>
<tr>
<td>20</td>
<td>BLEant003</td>
<td>Marble quarry</td>
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<td>1.00</td>
<td>0.50</td>
<td>0.00</td>
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</tr>
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</table>

Table 6: Geomorphosite assessment in the Blenio valley. Above: scientific value; below: additional values.


<table>
<thead>
<tr>
<th>Nr</th>
<th>Code</th>
<th>Name</th>
<th>Integrity</th>
<th>Represent.</th>
<th>Rarity</th>
<th>Palaeogeogr. value</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>LUCkar003</td>
<td>Karstic area</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>LUCkar005</td>
<td>Fluvial/karstic area</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>LUCgla001</td>
<td>Erratic boulder</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>LUCgla004</td>
<td>Ice cave</td>
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<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>0.94</td>
</tr>
<tr>
<td>5</td>
<td>LUCgla002</td>
<td>Granite/diorite glacial lock</td>
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<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
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<td>Alluvial zone</td>
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<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
</tr>
<tr>
<td>7</td>
<td>LUCpert01</td>
<td>Rock glacier</td>
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<td>1.00</td>
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<td>0.50</td>
<td>0.88</td>
</tr>
<tr>
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<td>LUCkar006</td>
<td>Residual landform</td>
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<td>0.25</td>
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</table>

<table>
<thead>
<tr>
<th>Geomorphosite</th>
<th>Ecological value</th>
<th>Aesthetic value</th>
<th>Cultural value</th>
<th>Economic value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Religious</td>
<td>Historical</td>
<td>Artistic Literat.</td>
<td>Geohist.</td>
</tr>
<tr>
<td>Rg</td>
<td>Code</td>
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</tr>
<tr>
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<td>LUCkar003</td>
<td>0.75</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
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<td>LUCkar005</td>
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<td>0.88</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>LUCgla001</td>
<td>0.25</td>
<td>0.75</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>LUCgla004</td>
<td>0.25</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>LUCgla002</td>
<td>1.00</td>
<td>0.88</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>LUCflu002</td>
<td>0.88</td>
<td>0.75</td>
<td>0.00</td>
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<td>LUCpert01</td>
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</tr>
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<td>LUCgla003</td>
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<td>0.00</td>
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<tr>
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<td>LUCflu001</td>
<td>0.50</td>
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<td>0.00</td>
</tr>
</tbody>
</table>

Table 7: Geomorphosite assessment in the Lucomagno area. Above: scientific value; below: additional values.


Fig. 1: Geomorphosites of the Blenio valley. Numbers relate to table 6.
Fig. 1 : Géomorphosites du Val Blenio. Les nombres se rapportent au tableau 6.
Fig. 1 : Geomorphologische Geotope im Val Blenio. Die Nummern entsprechen denjenigen in Tabelle 6.
3.2 The inventory of cultural geomorphosites in the Trient area

Within a project of promotion of cultural geomorphosites of the Trient area (Mont Blanc Massif, Valais, Switzerland) (REYNARD et al., in press), an inventory of geomorphosites focusing on the scientific and the cultural values has been carried out (fig. 2). The objective was to provide evidence of all the sites that could show the integration of natural and cultural aspects of landscapes (see PANIZZA & PIACENTE 2003). The inventory was carried out in two phases. A first selection of potential sites was made, based on the study of documents on the geomorphology and history of the valley. A complete assessment of each site (KOZLIK 2006) was then carried out by using the method described above. Because the focus was on the cultural value, the other additional values were not assessed.
Fig. 2: Cultural geomorphosites of the Trient area. Numbers relate to the 29 geomorphosites included in the inventory.

Fig. 2 : Géomorphosites culturels de la région du Trient. Les nombres concernent les 29 géomorphosites inclus dans l’inventaire.

Fig. 2 : Kulturelle geomorphologische Geotope in der Region Trient. Die Nummern entsprechen den 29 Objekten des Inventars.

The synthesis map of the cultural geomorphosites is presented in figure 2. The importance of the geocultural value is expressed by the size of the circle and the distinction of each circle in two parts (above and below) represents the contribution of each element – geomorphology and culture – to the global value. This inventory is now contributing to the tourist promotion of the geocultural heritage within several projects (see REYNARD et al., in press).

4 Conclusion

The methods developed previously for assessing the geomorphosites focused essentially on the scientific quality of sites (e.g. RIVAS et al. 1997, GRANDGIRARD 1999, BRUSCHI & CENDRERO 2005, CORATZA & GIUSTI 2005, SERRANO & GONZALEZ TRUEBA 2005). They were used mainly within inventories of natural goods and environmental impact assessment (EIA) studies. During the last decade, the promotion of geoheritage has developed rapidly, due to the creation of geoparks and the development of geotourism. In this context, the assessment of geomorphosites needs to include also additional values (e.g. cultural, ecological, etc.) in the evaluation process. The aim of the proposed method is therefore to combine the assessment of the central scientific value and several additional values.

The method was developed with two main objectives: an objective of simplicity, in order to be used by students and by research departments, and an objective of exhaustiveness. Because the method aims at evaluating not only the scientific value of sites – as most of the existing methods do –, but also the additional values, it opens new perspectives in the area of geoheritage conservation and management. Indeed, the two case studies were carried out in quite a large context. The first one (Blenio-Lucomagno area) was related to the creation of a National Park. The project is led by non-geomorphologists and the original project did not take the geomorphology into account at all. Our objective was, therefore, to show – by the realisation of the inventory – the importance of geomorphology for the biodiversity of the area. It was important to bring to light which sites have an important ecological value (tables 6 and 7 show that several sites have a maximum score in this criteria). The map in figure 1 shows, moreover, that several sites with a particularly important scientific value (large circles) and a dominant ecological additional value are situated in the North of the Blenio valley, in the area of the project of a National park. This concentration allows us to propose a specific didactic promotion of the relationships between geodiversity and biodiversity to be realised in this part of the park.

The second example shows that the method can be adapted to the objective of the evaluation. In this case, the assessment was carried out in relation to several projects of heritage and tourist promotion of the Trient area. The aim was, therefore, to show the relationships existing between the geomorphology and the social and cultural development of the valley, especially tourism history. The focus on one additional value – that is the cultural one –, allowed us to bring to light this particular link. The inventory of cultural geomorphosites is currently used as the basis for the realisation of several tourist and didactic products created in a context of promotion of eco- and geo-tourism in the area.

The assessment card is now implemented in a GIS software. This new step will facilitate the realisation of spatial analyses (queries, classifications, etc.) and updating the data.
References


