Il Quaternario
Italian Journal of Quaternary Sciences
***18**(1), 2005 - Volume Speciale, 307-313*

METHODOLOGICAL PROPOSAL FOR THE ASSESSMENT OF THE SCIENTIFIC QUALITY OF GEOMORPHOSITES

Paola Coratza & Cecilia Giusti
Dipartimento di Scienze della Terra, Università di Modena, Largo S. Eufemia, 19, 41100 Modena (Italy)
Email: coratza.paola@unimore.it

ABSTRACT: P. Coratza & C. Giusti, *Methodological proposal for the assessment of the scientific quality of geomorphosites.* (IT ISSN 0394-3356, 2005).
The method proposed has been elaborated for assessing the Scientific Quality of Geomorphosites. This method is quantitative, but a series of qualitative guide lines has been elaborated, in order to give a support for the attribution of values. Scientific quality is calculated considering a series of parameters: expert's knowledge (educational value and research value); areal extent; rarity; degree of conservation; exposure and an added value (related to the importance that the asset has for non-geomorphological aspects that nevertheless can increase its scientific value). Afterwards, each parameter had to be weighted. This methodology could become a useful tool for optimizing decisional processes within the framework of Territorial Planning, Environmental Impact Assessment and Protection of the Natural Heritage.

RIASSUNTO: P. Coratza & C. Giusti, Proposta metodologica per la valutazione quantitativa della qualità scientifica di geomorfositi*. (IT ISSN 0394-3356, 2005).*
Viene illustrata una metodologia per la valutazione quantitativa della qualità scientifica dei Geomorfositi. Questa proposta metodologica vuole essere un esempio di come si possa arrivare a valutazioni di tipo quantitativo, al fine di poter rendere la procedura di valutazione più obiettiva possibile, attraverso ragionamenti logici e espressioni qualitative. In particolare la Qualità scientifica (Q) del Geomorfosito viene calcolata considerando una serie di parametri, alcuni strettamente legati alla connotazione scientifica del bene, altri indirettamente. Questi parametri sono: la conoscenza dell'esperto, l'estensione areale, la rarità, il grado di conservazione, l'esposizione e il valore aggiunto. Successivamente si procede all'attribuzione di un peso ad ogni parametro e alla quantizzazione della qualità scientifica del bene mediante una formula. La metodologia proposta è uno strumento utile per ottimizzare il processo decisionale nel campo della Valutazione d'Impatto Ambientale (VIA), della Pianificazione Territoriale e della salvaguardia del Patrimonio Geologico.

Keywords: Geomorphosites, Assessment, GIS.

Parole chiave: Bene geomorfologico, Valutazione, GIS.

1. INTRODUCTION

According to the definition given by Panizza (2001), a Geomorphosite is a landform with particular and significant attributes which qualify it as a component of the cultural heritage (in a wide sense) of a given territory. Attributes which can confer value to a geomorphosite are the scientific, cultural (in a strict sense), socioeconomic and scenic attributes. Therefore, with this meaning Geomorphosites make up the landscape, habitat, elements of geodiversity, knowledge of the dynamics of the Earth's past, memory of biological evolution and Man's life from its very beginning, and essential resources for economic and scientific development. As such, Geomorphosites deserve to be treated with a correct and appropriate management and conservation policy.

In the past few years the ever-growing interest in Cultural and Environmental Assets has underlined the demand for operators possessing adequate tools for the correct assessment, conservation and management of all these assets. Hence the need to select those aspects of the landscape that more than any others deserve to be identified, known and safeguarded. Indeed, only by recognizing the intrinsic value and hierarchic rank of each single element with respect to all the objects found within the system considered, will it be possible to guarantee the correct policy of environmental management (Scarelli & Poli, 1999). For this purpose, a quantitative assessment of Geomorphological Assets must be carried out in order to compare these assets or other environmental and non-environmental assets and select them, especially within the framework of Territorial Planning or Environmental Impact Assessment (EIA) procedures. All these approaches are necessary in order to develop possible strategies and define priorities and scales of values.

In literature numerous methods are described for the quantitative assessment of landforms. The earliest go back to the 1970s and were generally developed by scholars from English-speaking countries, in particular from the United States. Worthy of note are the assessment procedures by Linton (1968), Leopold (1969) and Fines (1968). Some of these propose morphometric measurement methods of diverse landscape components which are considered representative of the scenic quality of a landscape. Others are more subjective and concern the perception of a whole landscape in quantitative terms (Panizza & Piacente, 2003). Nevertheless, the limits of these assessment procedures are considerable, because they are either too subjective or based on an unnatural subdivision of geomorphological assets.

Starting from these preliminary remarks, an experimental methodology for a quantitative assessment of the scientific quality of Geomorphological Assets was defined and applied to a study area of the Modena Province plain (Emilia-Romagna Region), which was chosen as an example area.

The method here illustrated was set up by utilising GIS techniques, which are the most suitable instrument for the implementation of a dynamic, updateable and ductile system for the selection, census, mapping and quantitative analysis of Geomorphological Assets. In addition, this system can be used in specific applications such as Environmental Impact Assessment, Territorial Planning and Conservation of Natural Heritage (Coratza & Giusti, 2003). In particular, GIS techniques allowed data and attributes relative to the assets described in the study area to be linked to the CTR topographic map at a 1:25,000 scale in raster format. Furthermore, by means of this software a new system was created, capable of comprehending the collection, modelling and analysis of data produced in the previous phases. It can therefore be a useful instrument for optimising decisional procedures in the field of territorial planning and safeguard of Geological Heritage.

2. METHODOLOGY

The proposal here presented is meant to offer an example of how quantitative assessments can be attained by means of logical reasoning and qualitative expressions. In particular, the scientific quality of an Asset is evaluated by means of several parameters, some of which are directly linked to the scientific identity of the Asset whereas others are only indirectly related to it. The elaboration of this methodology is based on several previous investigations (Panizza *et al*., 1995; Barba *et al*., 1997, Rivas *et al.*, 1997; Bertacchini *et al.*, 1999; Giusti & Gonzalez, 2000) and can be considered a useful tool in Territorial Planning and Environmental Impact Assessment.

This methodology, directed to geomorphological assets and applied by using the "ILWIS 2.2" and "ArcView 3" Geographical Information Systems (GIS), can be subdivided into four phases: geographic-geomorphological study of the area considered, selection of Assets, assessment of scientific quality, and calculation of impacts.

2.1. Geographic-geomorphological setting of the study area

The first investigation phase consisted of bibliographic research on the most significant scientific studies carried out on this topic. The research allowed reconstruction of the evolution and transformations occurring in historical times in the Modena plain. Furthermore, the interpretation of multiscalar and multitemporal aerial photographs and field surveys allowed an updated geomorphological map and a digital terrain model (DTM) of the Modena plain to be realised. These documents are indispensable for selecting and mapping geomorphological sites.

The Modena plain is located in the south-central portion of the Po Plain and is bounded to the north by the Province of Mantova, to the east by the Provinces of Ferrara and Bologna, to the south by the Apennine foothills and to the west by the Province of Reggio Emilia. The study area, which covers a total extension of about 1348 km^2 (Fig. 1), is represented in the following Emilia-Romagna CTR sheets at a 1:25,000 scale: 183 NE, 183 SE, 183 SO; 184 NE, 184 SE, 184 SO, 184 NO; 185 SO; 201 NE, 201 SE, 201 SO, 201 NO; 202 NE, 202 SO, 202 NO; 219 NE, 219 SE, 219 NO, 219 SO; 220 NO.

The territory under investigation stretches from north to south at elevations between 175 m to 7 m a.s.l. and, from the altitude viewpoint, can be subdivided into high, middle and low plain (Various Authors, 1997). The high plain is comprised between the Apennine foothills and the Via Emilia, with elevations of 175 m to 50 m and corresponds to the alluvial fans of the main Apennine watercourses. The middle plain is comprised between the Via Emilia and the 20 m contour line. The low plain is comprised between the 20 m and 7 m contour lines.

The morphological evolution of the Modena plain has mainly been conditioned by the evolution of the two main rivers that cross it: the River Panaro, which flows along the eastern extremity of the province's territory and the River Secchia, which flows along the western extremity. Indeed, numerous landforms occurring all over the territory result from present hydrography and ancient hydrography: fluvial ridges, ancient riverbeds, inundation fans, terraces, meanders, water springs etc. (Castaldini, 1989). However, in more recent decades another element has increasingly conditioned the landscape: Man with his various activities such as

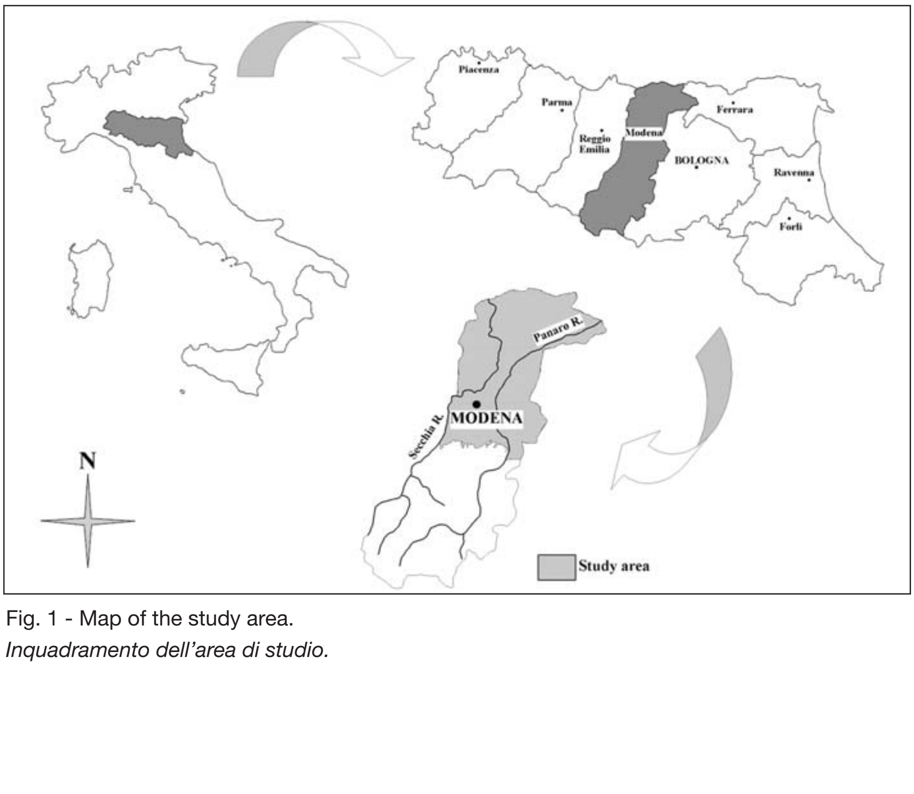


Fig. 1 - Map of the study area.
Inquadramento dell'area di studio.

quarrying, hydraulic works (e.g., meander cuts, artificial canals, flood mitigation structures) and urban development.

2.2. Selection of Geomorphological Assets

The selection of Geomorphological Assets was made by starting from the geomorphological vectorial map of the Modena plain and from the DTM. Both these documents were elaborated by means of GIS ILWIS 2.2 and ArcView 3 programmes. This DTM, equipped with a *shadow* filter (Fig. 2), can reconstruct the natural relief trend since contour lines (difference in altitude: 1 m) were traced without considering points corresponding to anthropogenetic structures (Giusti, 2001). In addition, DTM is an indispensable tool for accurate reconstruction of plain area morphology and for a detailed representation of negative structures, such as hollow areas, and positive ones, such as rises. Subsequently, a georeferenced map (coordinate system: UTM) was realised with polygons representing the Geomorphological Assets of the Modena plain (Fig. 3). Finally, a table of attributes containing both the data inherent to the Assets' own characteristics and their quantitative assessment, was associated with this map (Fig. 4).

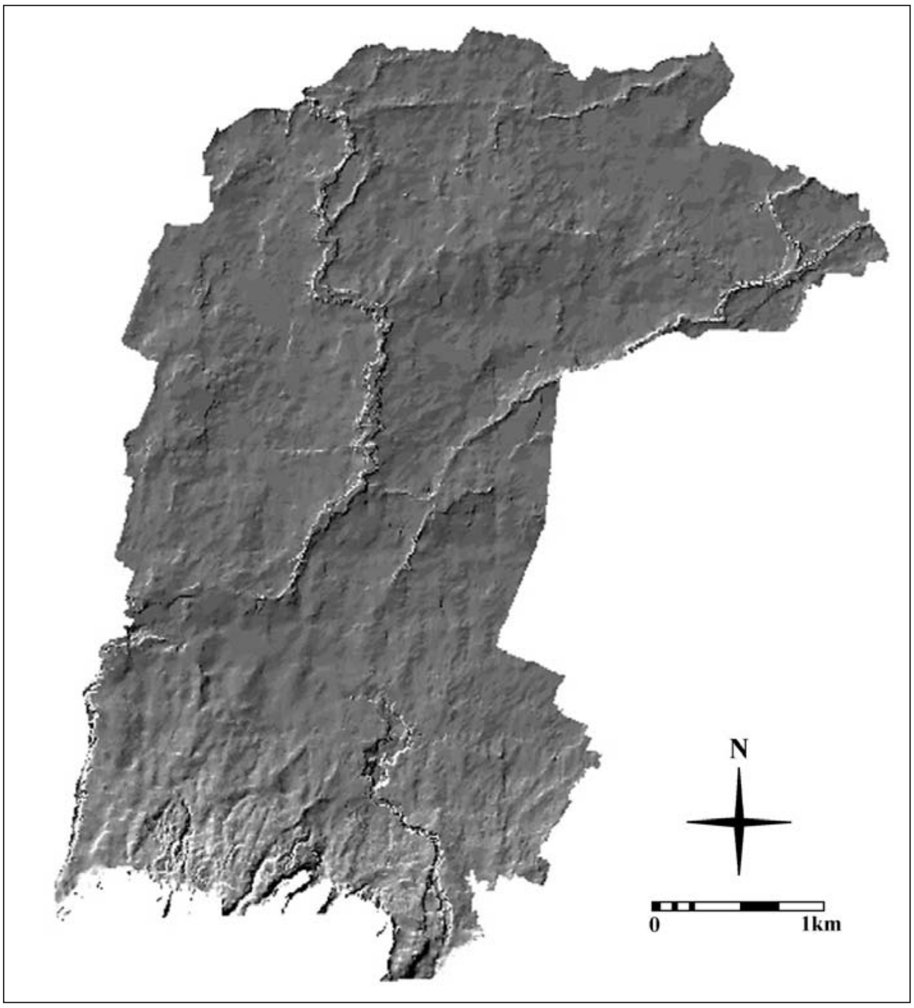


Fig. 2 - Digital Terrein Model (DTM) with shadow filter.
Modello Digitale del Terreno (DTM) con filtro shadow.

Thirteen Assets were eventually selected: examples of i) fluvial meanders of the Rivers Secchia and Panaro, which are now rare forms of the landscape owing to artificial straightening; ii) fluvial rises (Gavello and Ramo della Lunga), which in most cases were flattened by human activities; iii) ancient, abandoned meanders of the Rivers Secchia and Panaro with vegetation typical of wet areas; iv) water springs found at the boundary between highly pervious deposits and almost impermeable ones; only few of these springs survive owing to the overdraught from groundwater; v) fluvial terraces, both climatic and morphological, found along the boundary between the first Apennine reliefs and the upper plain.

2.3. Assessment of the scientific quality of Geomorphological Assets

In order to make this assessment procedure as objective as possible, guide-lines are recommended for an easy choice and subsequent assessment of a particular Asset. An important starting point is the geological and geomorphological knowledge of the study area.

In particular, the Scientific Quality (Q) of a Geomorphological Assets should be evaluated by means of several parameters, some of which are strictly linked to the asset's scientific specification whereas others are only indirectly connected to it. These parameters are:

- experts' knowledge (CE), which is linked to the Geomophosite's value for scientific research (S) and educational value (D);
- area (A), related to the total area occupied by similar Geomorphosites present in the stretch of territory considered;
- rareness (R), related to the quantity of similar Geomorphosites present in the stretch of territory considered;
- degree of conservation (C), which depends on both natural and anthropogenetic factors;
- exposure (E), in relation to visual impact;
- added value (Z), which is linked to the importance a Geomorphosite assumes owing to non-geomorphological aspects which, nevertheless, increase its scientific value (e.g., tourism, ecological characteristics etc.).

Eventually, a value will be assigned to each parameter after it has been adequately weighted.

Scientific Quality (Q) is calculated by means of the following formula:

$$Q = sS + dD + aA + rR + cC + eE + zZ$$

Where: S, D, A, R, C, E, Z are the values and s, d, a, r, c, e, z the respective weights. The latter, which range from 0 to 1, should be assigned to each parameter according to the guide-lines suggested.

1. Experts' knowledge (CE): experts are requested to express their opinion on two specific aspects which qualify Geomorphosites from the scientific standpoint: 1) value for scientific research (S) and 2) educational value (D).

1.1. Value for scientific research (S)
0.25 = low
0.50 = medium
0.75 = high
1.00 = very high

The Geomorphosite value for scientific research (S) can never be nil, otherwise a Geomorphosite could not be considered as such.

The value for scientific research should be assigned by considering the following guide-lines:

- number and quality of the scientific publications concerning a Geomorphosite;
- whether there are research programmes in progress concerning in some way a specific site;
- how representative a Geomorphosite can be for the evolutional reconstruction of the territory it is inserted in;
- whether a Geomorphosite is important for the History of Geomorphology in general;
- the added value that the study of a Geomorphosite can give to scientific research.

1.2. Educational Value (D)
0.00 = nil educational value
0.25 = low
0.50 = medium
0.75 = high
1.00 = very high

The Educational Value should be determined by considering the following guide-lines:

- representativeness of a particular form or process;
- whether a given Geomorphosite is quoted in educational textbooks as an Asset of a certain importance;
- whether a given Geomorphosite is inserted in some tourist/educational itinerary and which is the educational level of such an itinerary;
- whether it is known also outside the scientific world;
- a Geomorphosite is considered as having an educational value even if no educational material has so far been created on it.

2. Area (A)

This parameter is calculated as the area of the Geomorphosite divided by the total area occupied by all the Geomorphosites of the same type in the area considered, expressed as a percentage.
0.25 = <25% of the total area
0.50 = 25 to 50% of the total area
0.75 = 50 to 90% of the total area
1.00 = 90 to 100% of the total area

The area value should be attributed by taking into account the following observations:

Fig. 3 - Distribution of Geomorphological Sites in the study area.

Carta dei Beni Geomorfologi nell'area di studio.

• Differently from other Geological Assets, the greater a Geomorphosite is, the higher is its value.

3. Rareness (R)

Rareness is assessed according to the quantity of similar elements present in the territory investigated.

0.25 = presence of numerous similar elements in the territory
0.50 = several similar elements in the territory
0.75 = very few similar elements in the territory
1.00 = unique example

The Rareness Value should be assigned by following these guide-lines:

• the rareness of a Geomorphosite is a very important factor, especially if it is affected by EIA or Territorial Planning procedures;
• rareness increases if the Geomorphosite bears witness to a morphoclimatic environment different from the present one.

4. Degree of Conservation (C)

This parameter (C) may depend on both natural and anthropogenetic factors.

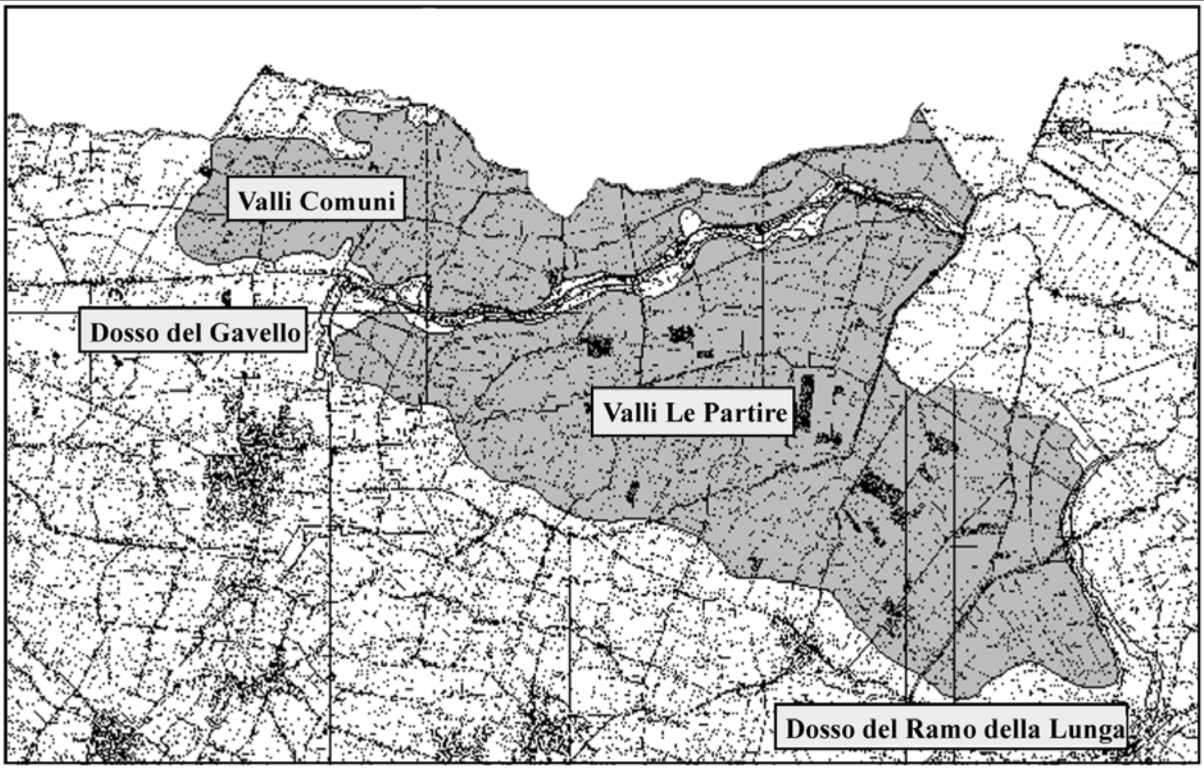
0.25 = poor state of conservation
0.50 = fair state of conservation
0.75 = good state of conservation
1.00 = excellent state of conservation

The degree of conservation should be assigned by considering the following guide-lines:

• the natural degree of degradation affecting a Geomorphosite;
• whether there are anthropogenetic elements which have altered or partially destroyed it;
• presence of acts of vandalism;
• whether there are structures that protect it from either natural or anthropogenetic agents.

5. Exposure (E)

Exposure is considered as the visibility of a



Bene	Località	Note	Tipologia
Dosso del Gavello	Quarantoli, Gavello	/	Dosso fluviale
Ramo della Lunga	Finale Emilia	/	Dosso fluviale
Valli Le Partite	Gavello, Finale Emilia	Oasi Faunistica "Valli di Mortizzuolo"	Area depressa
Valli Comuni	Quarantoli, Gavello	/	Area depressa

Bene	Area	DP	SP	DEG	SEG	A	R	Z	C	E	Q	QN
Dosso del Gavello	2814825	0,20	1,00	0,25	1,00	0,75	0,80	0,25	0,50	1,00	4,25	1,0
Ramo della Lunga	1118091	0,20	1,00	0,25	1,00	0,50	0,80	0,25	0,75	0,75	4,11	1,0
Valli Le Partite	80191143			1,00	1,00	0,75	0,50	1,00	0,75	1,00	3,86	1,0
Valli Comuni	31624635			0,25	0,75	0,50	0,50	0,50	0,75	1,00	2,67	0,0

Fig. 4 - Zoom on the map of Geomorphological Sites and associated table.
Zoom sulla carta dei Beni Geomorfologici e tabella associata.

Geomorphosite.
0.25 = the Geomorphosite is heavily penalized
0.50 = the Geomorphosite is penalized
0.75 = the Geomorphosite is not particularly penalized
1.00 = the Geomorphosite is not penalized at all

The degree of exposure should be assigned by considering the following guide-lines:

- a Geomorphosite is suffocated by human development and, in order to see it properly, one must go very close to it;
- reaching a Geomorphosite may be very difficult;
- presence of human structures which disturb the sight of a Geomorphosite from far away;
- presence of human structures which disturb the sight of a Geomorphosite from a close position;
- a Geomorphosite is visible from all visual angles;
- a Geomorphosite is located in a panoramic point and emerges over the surrounding landscape.

6. "Added Value" (Z)

Added Value (Z) is the "level of awareness" of a Geomorphosite as such, owing also to non-geomorphological features, although geomorphology remains the main conditioning factor.
0.00 = nil added value
0.25 = added value of low importance, at a level of local curiosity
0.50 = added value of fair importance
0.75 = added value of high importance
1.00 = added value of fundamental importance, without which a specific Asset would lose a considerable amount of its geomorphological value

The Added Value should be assigned by considering the following guide-lines:

- the Geomorphosite has also a certain ecological and/or naturalistic value;
- around the Geomorphosite there are geological elements that further "enrich" it;
- the Geomorphosite has a certain tourist-economic value;
- the Geomorphosite has a certain historical-cultural value;
- the Geomorphosite lies within a protected area.

The Q value thus obtained is therefore normalised in order to obtain values of 0 to 1, according to the formula: $Q = Q_n / Q_{max}$. Where: Q_n = Scientific Quality of a Geomorphosite and Q_{max} = maximum value that a Geomorphosite can express.

The values obtained are listed in tab. 1.

3. FINAL REMARKS

The proposed methodology makes use of GIS for a quantitative assessment of Geomorphological Assets because it is a useful tool for optimising the decision-making procedure in Territorial Planning and in safeguarding Geological Heritage.

The method developed in this work can be applied to advantage particularly in plain areas where anthropization has reached extreme levels. It can also counteract the widespread but mistaken belief that the landscape of the plain lacks any kind of interesting morphological elements.

It must, however, be said that although the proposed methodology is quantitative, there is inevitably a degree of subjectivity in the assessment and quantification of environmental elements as their true value cannot really be measured. Moreover, the allocation of values to the parameters used largely depends on the experience and sensitivity of the expert involved in assessment.

The scientific quality of an asset is a purely indicative numerical quantity which can be subject to variations determined by the subjectivity of the operators

Tab. 1- Quantitative assessment of the scientific quality of the Geomorphological Sites.
Valutazione quantitativa della qualità scientifica dei Beni Geomorfologici.

GEOMORPHOSITES	D	S	A	R	Z	C	E	Q	Q_N
Springs of Castelfranco Emilia	0,25	0,75	1,00	0,80	0,25	0,25	0,75	2,75	0,4
Spring of Montale	0,50	0,75	0,25	0,80	0,50	1,00	0,50	2,81	0,4
Meander of R. Panaro	0,25	0,50	0,50	0,50	0,25	0,75	0,50	2,25	0,3
Meander of R. Secchia	0,25	0,50	0,75	0,50	0,25	0,75	0,50	2,50	0,7
Palaeomeander of R. Panaro	0,25	1,00	0,50	0,80	0,50	0,75	0,75	3,60	0,4
Palaeomeander of R. Secchia	0,25	0,50	0,75	0,80	0,50	0,50	0,75	2,90	0,6
Gavello alluvial ridge	0,25	1,00	0,75	0,80	0,25	0,50	1,00	4,25	0,4
"Ramo della Lunga" abandoned fluvial course	0,25	1,00	0,50	0,80	0,25	0,75	0,75	4,11	0,6
Alluvial terraces of R. Fossa	0,25	1,00	0,25	0,80	0,50	0,75	0,75	3,67	0,4
Alluvial terraces of F. Panaro	0,25	0,75	1,00	0,50	0,50	0,50	0,50	3,40	0,6
"Valli Le Partite" low-lands	1,00	1,00	0,75	0,50	1,00	0,75	1,00	3,86	0,5
"Valli Comuni" low-lands	0,25	0,75	0,50	0,50	0,50	0,75	1,00	2,67	0,6

and the general characteristics of the area under examination. But in spite of this, there is a real attempt to express each geomorphological asset's scientific importance numerically so as to be able to compare them, even when there is some discrimination due to scientific dishomogeneity.

In this context, the correct classification of natural and geomorphological assets together with an evaluation of their vulnerability is essential if we want to analyze the relationship between human activities and natural processes involving the modelling of the physical environment.

This approach is an indispensable part of environmental impact assessment procedures, especially in the case of territorial priorities. In order to obtain the best results, it is advisable to have the method applied by a group of experts, acting independently, in order to give an estimate of each result, for example, by utilising the *Delphi* method (Balkey, 1969).

REFERENCES

Barba F.J., Remondo J., & Rivas V. (1997) - *Propuesta de un procedimiento para armonizar la valoración de elementos del patrimonio geológico* - ZUBIA, n. 15, pp. 11-20.

Bertacchini M., Giusti C., Marchetti M., Panizza M. & Pellegrini M. (eds.) (1999) - *I Beni Geologici della Provincia di Modena* - Artioli Editore, Modena, 104 pp.

Coratza P. & Giusti C. (2001) - *GIS e valutazione di Beni Geomorfologici: un esempio nella pianura modenese (Emilia Romagna)* - GEOSTORIE, Bollettino e Notiziario del Centro Italiano per gli Studi Storico-Geografici, Università di Firenze, CD-Rom.

Castaldini D. (1989) - *Evoluzione della rete idrografica centropadana in epoca protostorica e storica* - Atti del Convegno Nazionale di Studi "Insediamenti e viabilità nell'Alto Ferrarese dall'età romana al Medioevo" - Cento 8-9 maggio 1987. Accademia delle Scienze di Ferrara e Centro Studi "G. Baruffaldi" di Cento, pp. 113-134.

Giusti C. (2001) - *Il Modello Digitale del Terreno (DTM) come supporto alla cartografia geomorfologica: l'esempio della pianura modenese (Pianura Padana, Italia settentrionale* - In: G. Scanu (ed.), *Cultura Cartografica e Culture del Territorio*, Atti del Convegno Nazionale (Sassari 12-13 dicembre 2000), Bollettino dell'Associazione Italiana di Cartografia, 111-112-113, pp. 409-417.

Giusti C. & González-Díez A. (2000) - *A methodological approach for the evaluation of impacts on sites of geomorphological interest (SGI),using GIS techniques* - In: K.J. Beek & M. Molenaar (eds.), *International Archives of Photogrammetry and Remote Sensing*, Proc. XIX Congress of the International Society for Photogrammetry and Remote Sensing, Amsterdam 2000, vol. 23, Part suppl. 7B, pp. 47-53.

Leopold L.B. (1969) - *Landscape Aesthetics* - Nat. History, 10, pp. 35-46.

Linton D.L. (1968) - *The assessment of scenary as a natural resource* - Scott. Geogr. Mag., 84, pp. 218-238.

Panizza M. (2001a) - *Geomorphosites: Concepts, methods and examples of geomorphological survey* - Chinese Science Bulletin, 46, pp. 4-6.

Panizza M., Marchetti M. & Patrono A. (1995) - *A proposal for a simplified method for assessing impacts on landforms* - ITC Journal 1995-4, 324.

Panizza M. & Piacente S. (1999) - *Il concetto di "bene" nel paesaggio fisico* - In: M. Bertacchini, C. Giusti, M. Marchetti, M. Panizza & M. Pellegrini (eds.), *I Beni Geologici della Provincia di Modena*, Modena, Artioli Editore, 8 pp.

Rivas V., Rix K., Francés E., Cendrero A., & Brunsden D. (1997) - *Geomorphological indicators for environmental impact assessment: consumable and non-consumable geomorphological resources*, Geomorphology, 18, pp. 169-182.

Scarelli M. & Poli G. (1999) - *Quale strategia per una difesa attiva della natura*?- In: G. Poli (ed.), *Geositi testimoni del tempo*, Regione Emilia-Romagna, Bologna, pp. 100-103.

Various Authors (1997) - *2ª Relazione sullo stato dell'ambiente nella Provincia di Modena*, Provincia di Modena, Modena, Mucchi Editore.