GIS and geomatics application for the evaluation and exploitation of Piemonte geomorphosites

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1. Introduction

Landscape is a complex combination of landforms and processes in constant change. These forms and processes are important evidence of the Earth's history and enable us to understand the evolution of our world (Avanzini et al., 2005). Geomorphological heritage may refer to a collection of sites of geomorphological interest defined as geomorphosites (Panizza, 2001). In this paper, the term "geomorphosites" is used to refer to geomorphological landforms, which are important for the knowledge of Earth history and characterised by scientific, cultural/ historical, aesthetic and social values on the basis of human perception and appraisal (Panizza & Piacente, 1993; Panizza, 2001).

Among Italian regions, the Piemonte (Piedmont) is noteworthy because of its variety of environments and, similarly to other regions, it has started an activity of acknowledging, describing and making sites, which bear witness of the Earth history, available for people. In the past few years, several attempts to investigate the geological heritage of the Piemonte region were carried out. The first step was the publication of the "*Carta geomorfologica degli elementi di interesse paesaggistico del Parco Nazionale del Gran Paradiso*" (Giardino & Mortara, 2001). Subsequently, a remarkable impulse was given by the publication of two books for the general population on the appraisal of geomorphosites in Turin Province (Giardino & Mortara, 2004). At the end of 2004, the cooperation between the managing Authority of Asti Province Natural Parks and the Department of Earth Science of Turin University, allowed the inventory of 219 geosites located in the Asti Province and the Turin hills (Various Authors, 2004).

This paper describes the steps followed to evaluate and appraise the geomorphological heritage located in the southern Piemonte plain (Cuneo Province) by means of assessment procedures, GIS (Geographic Information System) and geomatics instruments. It suggests programs of appraisal and popularisation by means of GIS and geomatics applications, in order to translate the complex Earth system with simple language, allowing a knowledgeable approach not only for the persons involved in the field of geosciences, but also for a general public and consultants involved in educational activities.

2. Geographical and geomorphological outline of the study area

The study area is located in north-western Italy, in the Cuneo province (Piemonte Region, Fig. 1). To the south, the area extends as far as the town of Bene Vagienna; it encloses the Stura area of the Demonte River to the west, the Tanaro River to the east; and to the north, the area extends as far as the urban centres of Bra and Pocapaglia.

From the geomorphological viewpoint, the area can be divided into two sectors. The first one is characterised by river terraces standing out as islands from the plain. The morphogenesis of these landforms is due both to Pleistocene climate changes and to the NNE diversion of the drainage system, triggered by neo-tectonic activity. The terraces consist of Pleistocene deposits; they gradually join with the main plain surface to the west; in other places they are abruptly connected to the present valley floors of the Tanaro and the Stura area of the Demonte rivers. To the east, the Pleistocene plateaux are grading to Holocene terraces suspended above the Tanaro riverbed. As a consequence of the capture of the Tanaro River, the whole terraces are cut by streams that dug deep gorges in their distal sector, where marine deposits of the Piemonte Tertiary Basin crop out (Costamagna, 2005).

The second sector is located in the north-eastern part of the study area. It is characterised by a complex set of narrow and deep valleys due to retrogressive river erosion, which is a consequence of the Tanaro NNE diversion. This kind of processes, at present no longer active, created badlands and dramatic landforms, locally well known with the name of “Rocche di Pocapaglia”.

3. Assessing the geomorphological heritage

In order to identify natural assets in a geomorphologically and scenically heterogeneous and complex region such as the one previously described, the inventory of the geomorphosites was carried out by the Earth Science Department of Turin University, based on a clearly defined methodological process. The first stages of the process were the study of both scientific and popular bibliographies, archive studies and analysis of specialised maps. The second phase was a detailed survey that resulted in the exploration of those areas considered the most representative for the geodiversity of the territory. In the whole area, ten geomorphosites of different contents and interests were identified, and eight of them were selected following the methodology proposed by Reynard et al. (2007). They all show a high educational value, allowing the understanding of the geomorphological evolutionary stages and the morphodynamic processes affecting this territory.

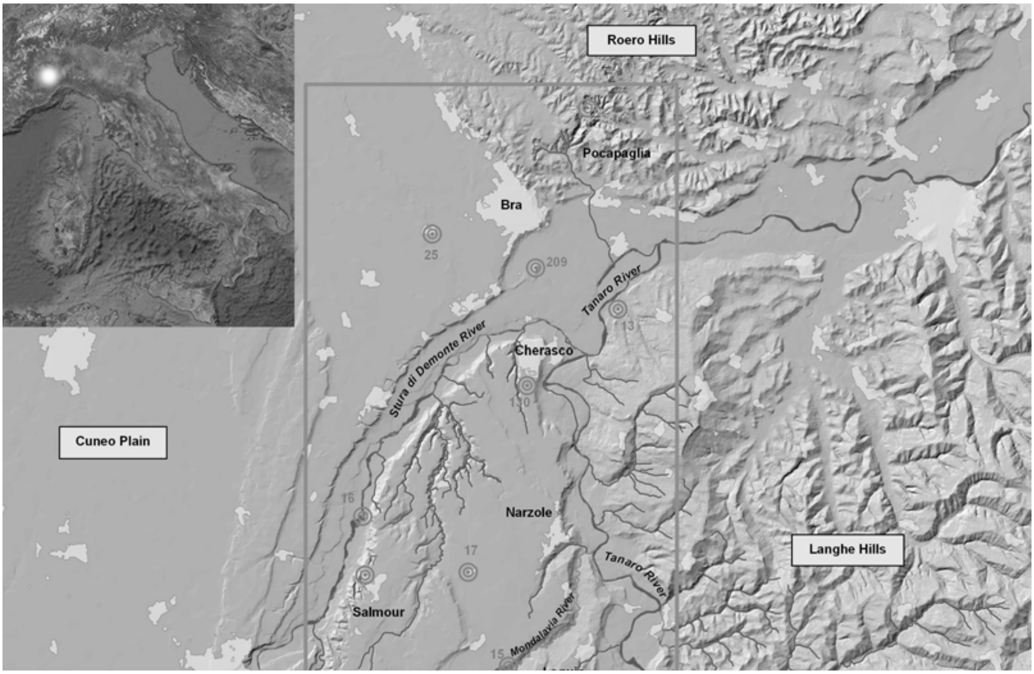

Fig. 1 Geomorphological outline of the study area and geomorphosites identified. 25 Valle relitta Tanaro; 209 Monte Capriolo; 13 Alveo del Tanaro; 130 Gola di Cherasco; 15 Forra del Mondalavia;16 Aveo dello Stura; 17 Altopiani di Benevagienna; 143 Rocca di Benevagienna.

All information was collected using description forms and maps loaded into a pocket PC (Fig. 2).

The description form holds all the fields requested by the Italian National Geological Survey (managed by ISPRA) and, in addition, it includes additional sections allowing the assessment of geomorphosites from scientific, aesthetic, accessibility, historical, cultural and ecological points of view. An experimental section was added concerning the main geomorphological hazards related to geomorphosites (Table 1).

Part one of the card deals with the collection of general data including location, description, essential features (forms and dimension, property, planning restrictions, soil use, lithology, chronostratigraphy, geomorphic age). Part two of the card deals with parameters for the assessment of the scientific value:

- rareness (rarity of the site);
- integrity (state of conservation of the site);
- representativeness (site exemplarity and educational value);
- paleogeographic value (importance of the site to tracing the geomorphological evolutionary stages of the study area).

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Scheda Inventario, Geosito N° 1

SOGGETTIVO [ ]

OGGETTIVO (spiegare): La grotta è un esempio di carsismo nei gessi unico a livello regionale, raro a livello nazionale. L'importanza del sito si può desumere dall'analisi dei documenti bibliografici citati.

D – DESCRIZIONE DELL'OGGETTO

Grotta carsica scavata in lenti di gesso cristallino (Solfato di Calcio biidrato) che, intercalate a marne e marne argillose, costituiscono il versante orografico destro del torrente Mellea (affluente di sinistra del fiume Tanaro). L'antro è composto da numerose cavità comunicanti, impostate lungo diaclasi a prevalente direzione Nord-Sud. Le gallerie presentano morfologia per metà vadosa (cunicoli stretti e alti), per metà freatica (soffitti piatti coincidenti con livelli marnosi). In entrambi i casi è evidente il sistema di fratture che ha influenzato lo sviluppo dei cunicoli. La grotta è caratterizzata dall'abbondanza di sedimenti, in prevalenza marnosi e a granulometria variabile (dalle argille ai blocchi). Essi sono in parte alluvionali, in parte derivano da crolli di materiale dall'alto. I frequenti massi che ostruiscono il percorso, la scarsità di tratti di pavimento orizzontale e la difficile identificazione della direzione di scorrimento dell'acqua fanno supporre che l'attività idrica recente sia stata minima e che prevalga quella gravitativa. Anche lo stillicidio dall'alto pare essere ostacolato dalla presenza di marne argillose al tetto della formazione gessoso-solfifera. Le cavità sono scavate in banchi di gesso balatino, fittamente stratificato in lamine millimetriche sub-orizzontali; meno di frequente si rilevano blocchi di selenite, costituiti da grossi cristalli singoli o geminati, e geodi. Fra i riempimenti della grotta esistono cristallizzazioni di cinabro (HgS) e di epsomite (Solfato di Magnesio eptaidrato), minerale che si presenta come efflorescenze sul pavimento delle gallerie a forma di sottili aghi fragili e deliquescenti. Vanno citati inoltre i depositi di guano di pipistrello: fino a pochi anni orsono la cavità ospitava ricche colonie di questo animale. L'accesso alla grotta, già nota per la presenza di un cunicolo nel fianco NE della collina a sud di Monticello, è oggi possibile attraverso sette aperture messe in luce dai lavori di coltivazione di una cava di gesso in sotterraneo.

E – DOCUMENTAZIONE FOTOGRAFICA (1)

SE NON ORIGINALE SPECIFICARE FONTE/AUTORE:

TIPO FOTOGRAMMA	FOTO	X	COD. AUTORE	AC
	DIAPOSITIVA		N° PROGR	1-4
	ALTRO			

F – DATI GEOLOGICO-CRONOSTRATIGRAFICI

F.1 – LITOLOGIA CARATTERIZZANTE
LENTI DI GESSO INTERCALATE A MARNE E MARNE ARGILLOSE PER LO PIÙ GESSIFERE (FORMAZIONE GESSOSO-SOLFIFERA)

F.2 – ETÀ CRONOSTRATIGRAFICA
MESSINIANO

F.3 – ETÀ DEL PROCESSO GENETICO
PLIOCENE - ATTUALE

G – TIPOLOGIA

FORMA SINGOLA: X — INSIEME DI FORME: [ ]

G.1 - FORMA		G.2 - DIMENSIONE		G.3 - ESPOSIZIONE	
LINEARE	X	LUNGHEZZA(m)	658	NATURALE	
AREALE		AREA (m^2)	14.000	ARTIFICIALE	X
		SPESSORE (m)	5		

Fig. 2 a Description form used during the inventory.

Fig. 2 b Pocket PC with maps.

Part three of the card deals with parameters for the assessment of aesthetic value:

- visibility;
- view points.

Part four of the card deals with parameters for the assessment of accessibility value:

- best way to access the site;
- road conditions;
- distance (potential) to be covered on foot and difficulty of the path; distance from facilities (hotels, restaurant, shops, etc.).

Part five and six of the card deal with parameters for the ecological and cultural-historical values: according to Reynard et al. (2007), the ecological section takes into account the importance of geomorphosites for the development of a particular ecosystem or the presence of particular fauna and vegetation, whereas the cultural-historical one takes into account several sub-criteria dealing with important religious, historical and literary aspects or popular legends.

The last part deals with the possible hazards relative to the use of geomorphosites, which, according to Panizza & Menella (2007), may be seen as dynamic components of the environment. This section contains information about: spatial characteristics of the area, potential frequency of the phenomenon, and a description of the hazards, also considering possible bad weather conditions.

It is possible to assign a quantitative value to the sections from 2 to 6 in order to obtain a table with a score for each geomorphosite, divided into scientific and additional values (Tables 2a, 2b). There are five possible values, expressed in part 1, with 0 reflecting no value and 1 a very high value. According to Reynard et al. (2007), the results from the scientific assessment and the mean of the results from the additional values are not combined in order to underline the different qualities of the two value sets. Geomorphosites with a low score in the scientific and additional values, or a low score in the scientific value and a medium score in the additional value have been discarded (Table 2c).

Parts	Criteria
1. General and descriptive data	Location, description, essential features
2. Scientific value	Rareness, integrity, representativeness, paleogeographical value
3. Aesthetic value	Visibility, view points
4. Accessibility value	Best method of access, road condition, path difficulty, distance to cover from facilities
5. Ecological value	Particular ecosystem or importance for fauna and vegetation
6. Cultural-historical value	Religious, historical, literary or popular legend
7. Geomorphological hazards	Spatial characteristics, potential frequency, bad weather conditions

Tab. 1 Parts of the description forms, including criteria used for evaluation.

	Integrity	Rareness	Representati-veness	Paleogeogra-phical value	Scientific value
Rocche di Poca-paglia	1	1	0,75	1	0,94
Valle Relitta Fiume Tanaro	0,75	0,25	1	1	0,75
Alveo del Tanaro a Cherasco	0,5	0,5	0,5	0,5	0,5
Monte Capriolo	0,75	1	1	1	0,94
Gola di Cherasco	1	0,25	0,75	1	0,75
Alveo dello Stura	0,5	0,75	0,25	0,75	0,63
Rocche di Salmour	0,75	0,25	0,25	0,25	0,38
Altopiani di Bene-vagienna	1	0,75	1	1	0,94
Rocca di Beneva-gienna	0,5	0,5	0,25	0,25	0,38
Forra del Rio Mon-dalavia	0,75	1	0,75	1	0,88

Tab. 2 a Geomorphosite assessment concerning the scientific value.

	Aestheticvalue	Accessibility value	Ecological value	Cultural-historical value	Additional value
Rocche di Pocapaglia	1	0,5	1	1	0,88
Valle Relitta Fiume Tanaro	0,25	1	0,25	0	0,38
Alveo del Tanaro	0,75	0,75	0,5	0	0,5
Monte Capriolo	0,25	1	0,25	0,75	0,56
Gola di Cherasco	0,75	0,75	0,75	0,75	0,75
Alveo dello Stura	0,75	0,5	0,5	0	0,44
Rocche di Salmour	0,5	0,75	0,5	0,5	0,56
Altopiani di Benevagienna	0,75	1	0,5	0,75	0,75
Rocca di Bebevagienna	0,25	1	0,25	0,75	0,56
Forra del Rio Mondalavia	0,5	0,75	0,25	0,75	0,56

Tab. 2 b Geomorphosite assessment concerning the aesthetic, accessibility, ecological and cultural-historical values.

	Scientific value	Additional value
Rocche di Pocapaglia	0,94	0,88
Altopiani di Benevagienna	0,94	0,75
Monte Capriolo	0,94	0,56
Forra del Rio Mondalavia	0,88	0,56
Gola di Cherasco	0,75	0,75
Valle Relitta Fiume Tanaro	0,75	0,38
Alveo dello Stura	0,63	0,44
Alveo del Tanaro	0,5	0,5
Rocche di Salmour	0,38	0,56
Rocca di Bebnevagienna	0,38	0,56

Tab. 2 c The geomorphosites final ranking. The last two sites have been discarted.

Data from bibliographic research, field survey and assessment results were stored using the relational database MySQL Community edition released under General Public License (GNU) (http://www.mysql.com) in order to reduce the costs of computer programme royalties. This structure consists of related tables, which also include fields that can be used to store binary data (images and multi-media contents). Furthermore, all information was organised in a methodical way in order to eliminate repetitions and queries, and making information retrieving much easier. The operation was implemented from the web with an interface written using PHP scripting language, which has full support for communicating with MySQL databases (Fig. 3a, 3b).

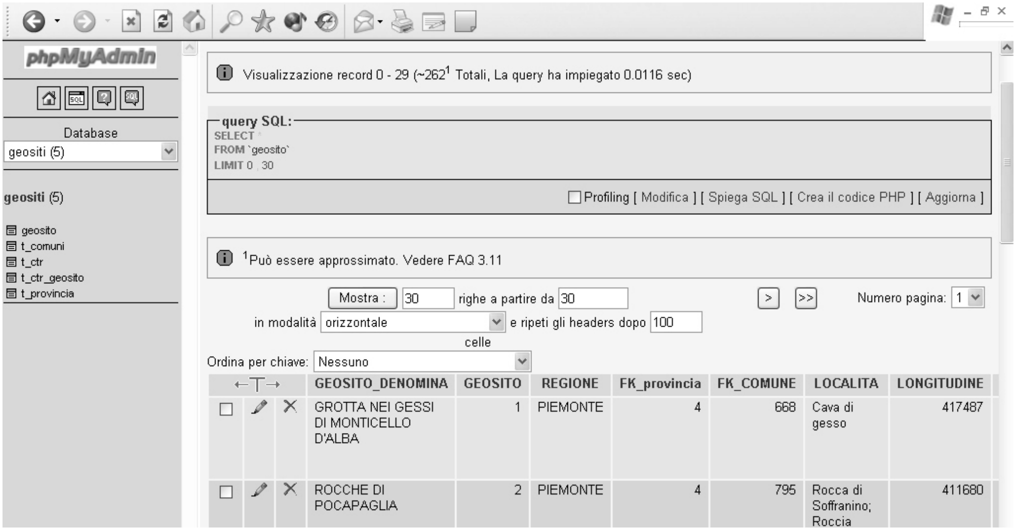

Fig. 3 a Graphic interface of MySQL DB.

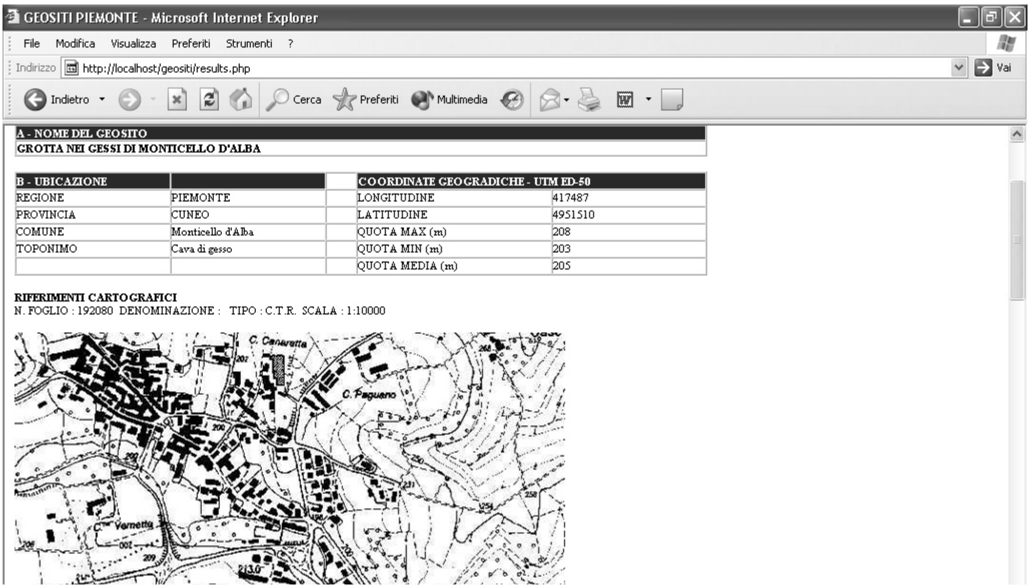

Fig. 3 b Web Interface to navigate MySQL DB.

4. Mapping issues

Data stored in the database created the basis for building a Geographic Information System (GIS) for geomorphosites, which allowed us to relate and combine various layer information with georeferenced data in order to produce thematic maps combining geological and geomorphological characters and other elements of the territory. Loading different layers and managing them at different scales is possible using zoom and pan procedures. Furthermore, with query tools it is easy to retrieve georeferenced "objects" on the map and to access the attributes associated with them.

The aim of this project was to develop a useful information tool, easy to access and suitable for people interested in the geomorphological assets for educational or tourist purposes. For this reason, it was very important to angle towards an application usable by the general public but at the same time preserving scientific rigour. Following the methodology developed by the University of Modena and Reggio Emilia (Castaldini et al., 2005a, 2005b; Bertacchini et al., 2007), a geomorphological map was created combining a terrain survey with the development of DEM (Digital Elevation Model) with a 7 m resolution and an orthomosaic with 70 cm resolution from a photogrammetric stereoscopic model (Fig. 4). At the end of the process, the geomorphological map was simplified leaving only the elements that can be easily observed and recognised by the general public within the area affected by the presence of geomorphosites.

Geographical data were organised in two different groups in order to provide a complete and exhaustive frame where basic information and geomorphological entities are located. The first group includes colour-shaded relief background derived from DEM raster cartographies, topographic maps and vector files providing information about characteristic features of the territory (utility services, network of infrastructures and tourist and cultural-historical features). The second group includes different layers, symbolising the main geomorphological features: geotourist itinerary, points of view or interest, and tourist information.

Using a GIS software, the scale problem is less important if compared with traditional maps but, in accordance with Carton et al. (2005), the accuracy of representation depends on the scale at which the data was mapped. In our case, geomorphosites were represented by dots on maps of 1:100,000 scale or less, whilst in large-scale maps they were represented by means of linear, point-like or polygon geomorphological symbols divided into different layers (Fig. 5a, 5b).

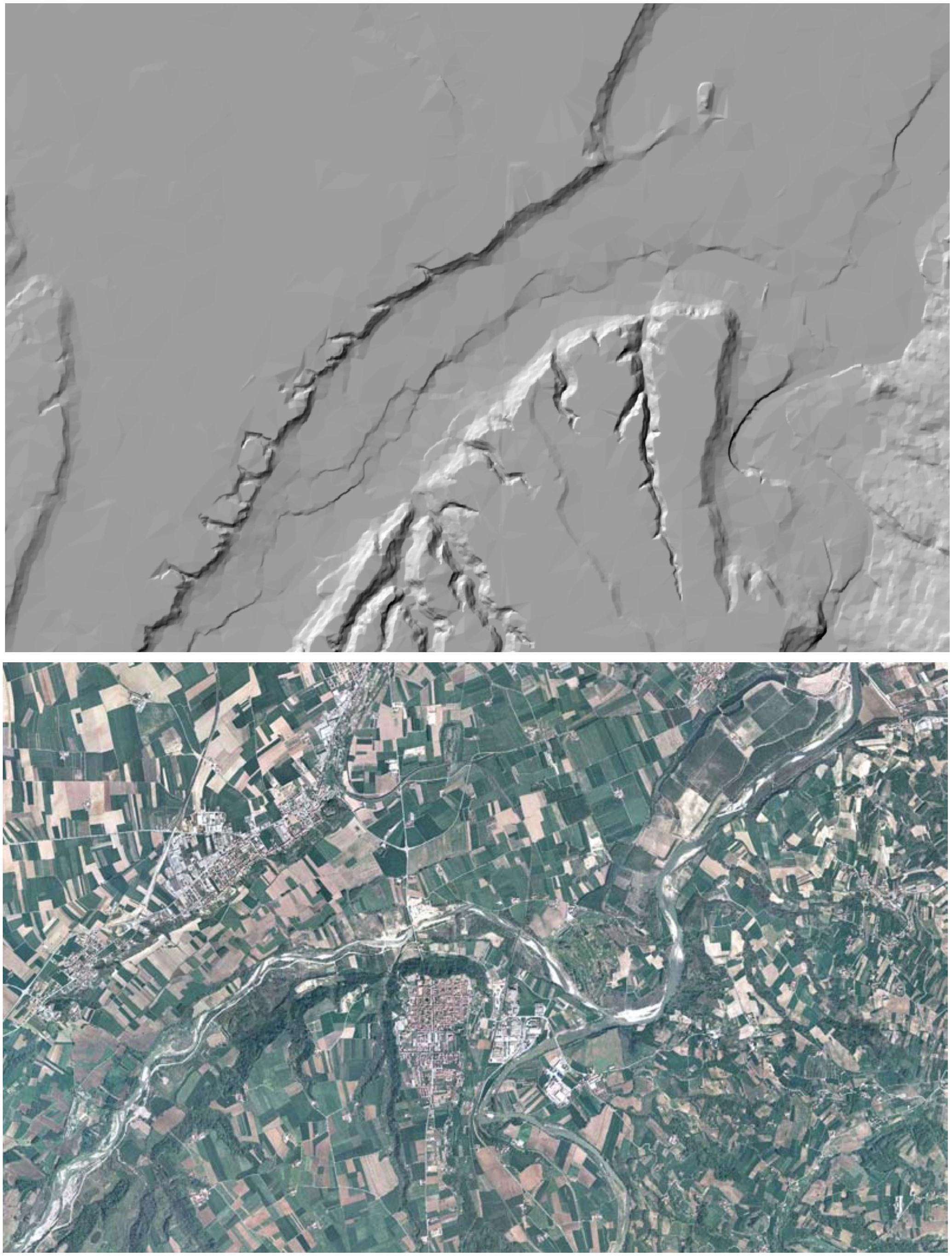

Fig. 4 Hillshade derived from DEM and orthomosaic obtained from photogrammetric steroscopic model.

The cards associated with each geomorphosite include four main sections:

- in the first section, a general outline of the geosite gives a description of the geomorphological features in relation to their formation processes;
- the second one contains a set of pictures, stratigraphic sections, 3D views and texts useful to understand the morphogenesis of the geosite and to relate it with the general evolution of the whole territory;
- in the third section, possible hazards were reported, informing users on potential dangers related to the use of the geomorphosite;
- in the last section, curiosities, popular legends, cultural or ecological notes concerning the geomorphosite and its relations with the surrounding environment and local traditions were reported.

Starting from the GIS project, and in order to promote the knowledge and appraisal of the selected geomorphosites, a Web-GIS application was then developed by integrating GIS and RDBMS (Relational Database Management System). It allows information to be shared among a wide range of users. Geographic data was implemented in a Web-GIS based on MapServer (http://www.mapserver.org) and P.Mapper (http://www.pmapper.net). Mapserver is an open source platform developed by the University of Minnesota. For this project, the MS4W package was installed, designed to perform a full installation of Apache, PHP, MapServer CGI and MapScript.

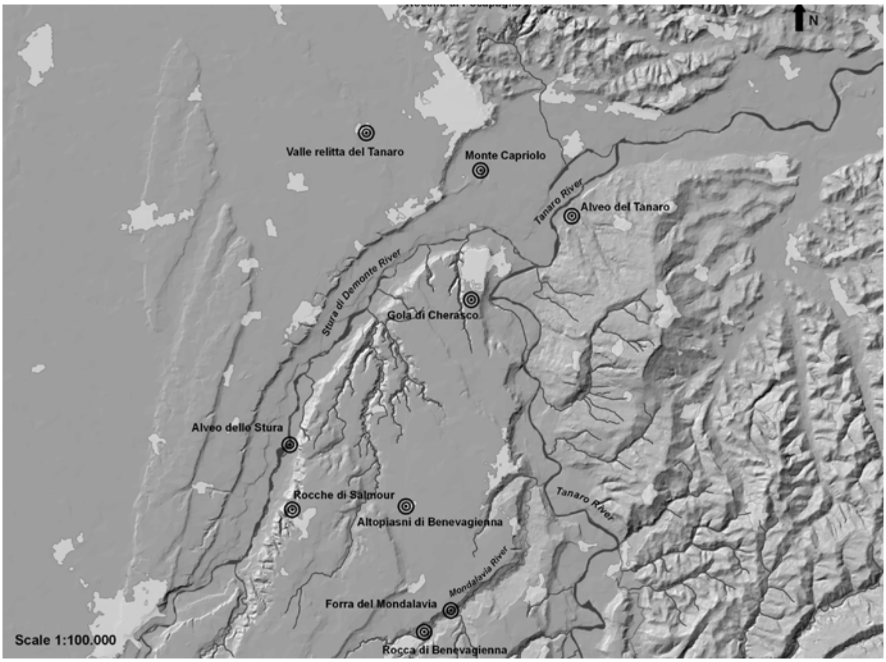

Fig. 5 a Geomorphosites in the study area represented with dots at 1:100,000 scale.

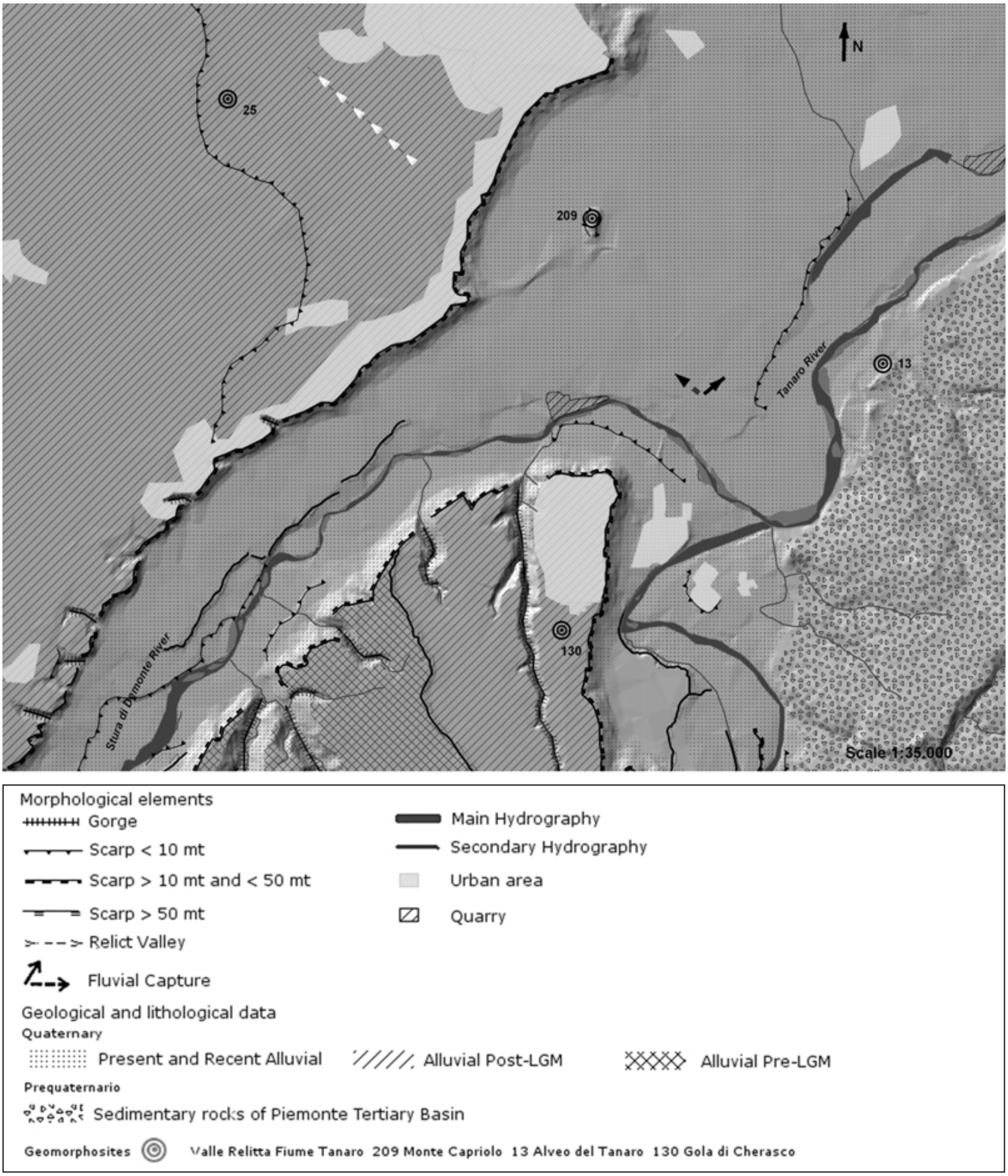

Fig. 5 b Portion of the study area at 1:35,000 scale. Geomorphosites are represented with a point-like symbol and with conventional geomorphological symbols.

P.Mapper is a framework, developed by DM Solutions, intended to offer broad functionality and multiple configurations in order to facilitate the set-up of a MapServer application based on PHP/MapScript. PHP scripting language has full support for communicating with the MySQL database and it allows objects represented in the Web-GIS application with MySQL database, and vice versa, to be linked together.

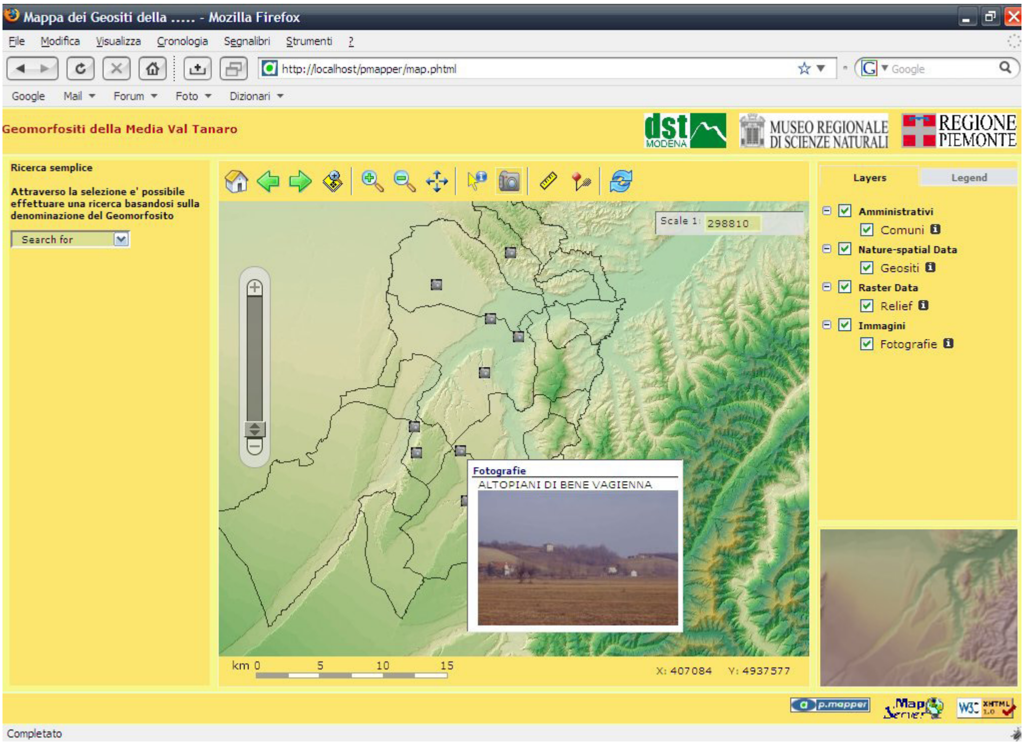

Fig. 6 Web-GIS application based on GIS project. Clicking on a hyperlink makes it possible to go back to the information stored in Web Server included in the MySQL Database.

5. Conclusion

Undoubtedly, the publication process on the Internet has shown the chance of translating the complex Earth system into simple language by means of a shared application providing users with a complete instrument for a free on-line use and a knowledgeable approach. Compared with traditional maps, Web-GIS applications present several advantages:

- they are cheaper if developed with Open Source software and less time-intensive to produce;
- they are easier to be distributed to a wide audience and easier to be updated and maintained;
- they allow interactive possibilities (e.g. the ability to change scales

and turn layers on/off) and connections to related information by means of hyperlinks.

Although it is tempting to think that Internet-based maps are preferable to paper maps in every way, this is certainly not the case. The most obvious disadvantages are:

- they require high band-width access to the Internet;
- they are vulnerable to server and network problems;
- they need a certain familiarity with GIS application.

The project described in this paper is still in progress and is open to future improvements, both for data increasing or updating and new system function implementation. The project was carried out in cooperation with territorial facilities such as local natural history museums, since their experience is absolutely necessary to obtain good results in a strategy of spreading scientific knowledge relative to the geological and morphological evolution of the territory of the Piemonte Region.

Acknowledgements

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