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SCIENCE

Mapping geomorphological values from a landscape perspective

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An easily applied methodology is developed for mapping geomorphological values from a landscape modelling perspective. The method is based on exhaustive fieldwork in which data are gathered relating to the structure and characteristics of relief, with the information weighted according to: (1) importance and significance in the area studied and (2) the viewsheds of prominent places. The procedure is applied in Muntanyes d'Ordal (Barcelona), with a large number of low-category values obtained.

Keywords: relief units; geomorphosites; viewshed; landscape; Muntayes d'Ordal

1. Introduction

The European Landscape Convention, signed in Florence in 2000, defines a landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (European Council, 2000). Landscape in this context has great environmental and social value, essential for sustainable development and territorial planning (Antrop, 2000). Landscape studies have always given great importance to questions concerning the structure and characterization of relief (Bolòs, 1992). This is due to the structuring role played by relief physiognomy in many landscapes (Gray, 2004; Knight, 2000). Geodiversity investigations study and classify areas that have geomorphological values of interest, and for this purpose they use different parameters for the values these areas hold, the processes that take place and the spatial scope of these processes (Panizza & Piacente, 2003; Reynard & Panizza, 2005; Serrano & Ruiz, 2007). Evaluating these areas involves predominantly lithologic, stratigraphic and geomorphic criteria (Bruschi, 2007; Wimbledon et al., 2000), with few scenic or visual criteria (González & Serrano, 2008; Reynard, 2004).

Evaluating the landscape takes into account not only the physical dimension of landscape elements but also their visual and psychological dimension (Sevenant & Antrop, 2009). In the evaluation process the landscape presents a physical reality independent of that perceived by the observer, endowing it with different attributes. There is thus no single evaluation procedure that is correct to the exclusion of all others. Hence the validity of the different methods tends to focus on recognizing a certain degree of subjectivity and ensuring that the results are systematic

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(Dunn, 1974), a process in which geographic information systems (GIS) are extremely useful (Martín & Otero, 2012).

The aim of this investigation is to design and develop a methodology for mapping geomorphological values from a landscape perspective. The study was applied in Muntanyes d'Ordal, an area of Mediterranean landscape near Barcelona (Spain).

2. Study area

Muntanyes d'Ordal is an area of medium-high mountains in the central sector of the Catalan Coastal Range, just a few kilometers from the city of Barcelona (Figure 1). This 15,000 Ha sector is characterized by the compartmentalization of relief, which consists of a series of valleys, peaks and ledges in a medium-high Mediterranean mountain context (Figure 2). The highest peaks are modest (Puig d'Agulles, 653 m) but the fragmentation and ruggedness are notable and clearly influence vegetation and human activity (Figure 3).

The dominant materials lie on a base of Cambro-Ordovician slate and shale, with abundant quartz dikes and a clear dip in a north-easterly direction. A border of Triassic materials is located on the Paleozoic series; in order of age there are five layers of Germanic facies, clearly stratified and well exemplified by shales and Buntsandstein conglomerates, Muschelkalk limestone materials and Keuper clays and evaporites. Finally, in terms of cover, there are Cretaceous limestones and dolomites, with a distribution and increasing thickness toward the southwest (Marqués, 1995).

Land cover consists of Mediterranean type tree and bush formations, scattered areas of dryland crops and a large number of low-density housing developments (Paül & Serrano, 2005).

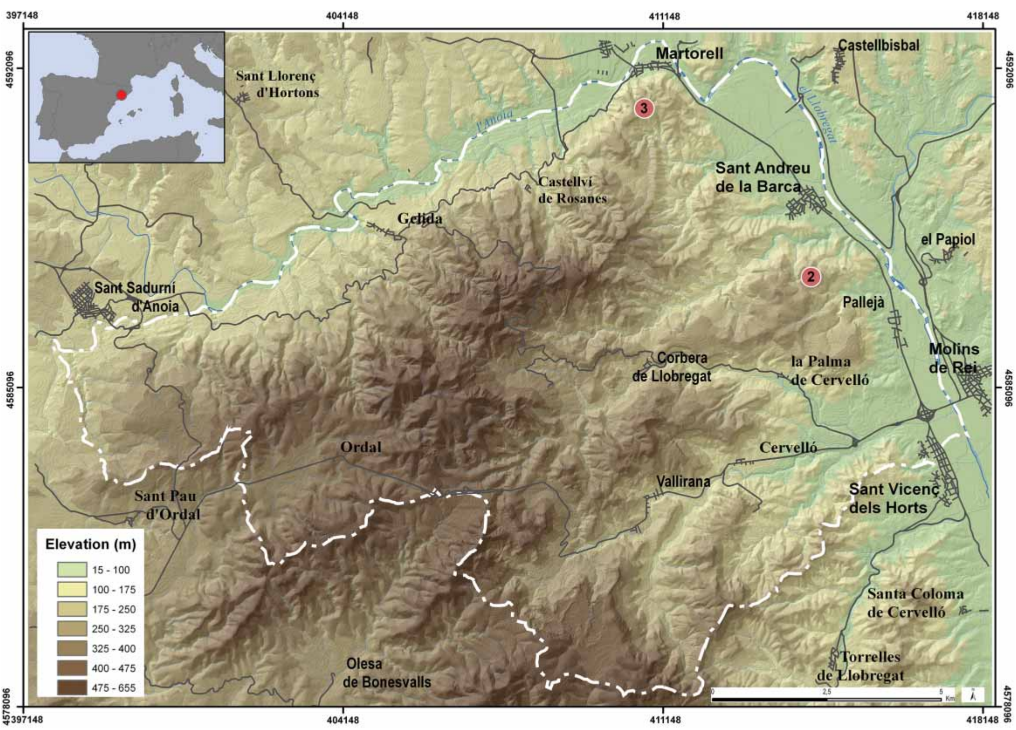

Figure 1. Location map of the studied area. Nb: studied area boundaries are shown in white. Number 2 and 3 dots shown Figure 2 and Figure 3 location on the map.

Figure 2. Les Planes de Pallejà. Relief en cuesta, cliff and associated plane, occupied by various human activities.

3. Methods

Basic information for the study was obtained by establishing homogeneous relief units. Homogeneous relief units are areas of land with similar topographic characteristics, morphostructure and morphodynamics. Extensive fieldwork was developed in order to gather data concerning the location, lithology, hydrography, deposits of materials, predominant and uncommon landforms. The aim of this exercise was to delimit homogeneous areas from the relief perspective, which have great importance in landscape, since they are easy to identify in reality. We distinguished six major substrate groups, five major landforms, four slope ranges and five families of landforms, which generated 408 groupings in 36 categories (Serrano 2012a). The systematic use of data within a GIS enabled us to georeference the information and incorporate it into a cartographic end product.

We located all distinctive geomorphosites, taking into account their immediate surroundings (denoted by the limits of the homogeneous relief units) and the values given to them by local people (Serrano, 2012b). Geomorphosites were understood as landforms with scientific, cultural, historical, aesthetic social and/or economic value to human perception or exploitation, according to Panizza's (2001) definition. Geomorphosites were located by fieldwork and identified considering both representative and scarce landforms, taking in to account their physical dimension and social importance. The main relief physiogomy was also considered through the use of the homogeneous relief units. Geomorphosites covered 1706 Ha, 11% of the entire area. Fieldwork was therefore useful in order to identify and classify common and outstanding geomorphosites, and for speaking with local people in order to quantify the significance of social and historical meanings.

Figure 3. Medieval ruins on Tertiary detrital material. In the background, industrial spaces in the metropolitan area of Barcelona.

We then calculated the viewsheds from each geomorphosite perimeter, in order to identify the maximum extent from which a geomorphosite could be seen. These viewsheds identify the portions of territory visible from each geomorphosite and conversely, the portions of territory from where it is possible to see at least one geomorphosite (Wade & Sommer, 2006). In our case, a standard value for the height of an observer (1.8 m) and a viewshed distance (4 km) were used. More than 85% of the area was visible from almost one geomorphosite viewshed.

Finally the three mapped variables (homogeneous relief units, geomorphosites and geomorphosite's viewsheds) were weighted and amalgamated. The units were weighted by calculating their relative participation in terms of surface in the area studied and then giving a positive value to the least represented units. A scale of 1 to 3 was used, with 1 being abundant and 3 scarce. To this end all units representing less than 33.33% of the whole were considered scarce, and all other above this percentage abundant. The geomorphosites were weighted by combining their uniqueness and, where applicable, the value given to them by local people. Again a scale of 1 to 3 was used, with 1 being common or relatively abundant and 3 uncommon or unique, and with great social recognition; to this end we used as a benchmark a 50 km buffer surrounding the area studied; the 50 km value is considered an appropriate choice as within this distance geomorphologic values show relative homogeneity in the study area. The viewsheds in each geomorphosite were classified by giving a value of 1 to each viewshed; the linear sum of all superimposed viewsheds was then calculated. This means that if it is possible to observe only one viewshed from a given sector, it is given a value of one; and if it is possible to see five viewsheds from a sector, it is given a value of five.

The three variables were amalgamated by adding the weighted values together. The result is expressed in five categories (very low, low, medium, high and very high) classified according to user-defined intervals.

4. Results and discussion

Thirty-six relief units were demarcated, valid at a scale of 1:20,000 (Figure 4). Within these units we located those places of the greatest importance or most significant character. Twenty-five geomorphosites were established which, also at a scale of 1:20,000, include all the most significant aspects of relief in the area (Figure 5). The viewsheds of each geomorphosite were then calculated in order to find the places from which one or more of these landscape elements could be observed (Figure 6).

The three layers of information were combined using a simple operation. The resultant mapping, produced at 1:25,000, brings together aspects related to the general relief structure, the landscape's most outstanding elements, and aspects of visual or scenic value (Main Map).

Using vector data within a GIS allows the production of high-quality maps. A total of more than one million polygons were involved, resulting from the combination of the three layers of information described above. Of these, 10.95% were under 5 m^2, the minimum mappable area for the final map scale (1:25,000); those units were merged in to adjacent polygons. A further 11.59% of the units had an area greater than the average (143 m^2). Six units had an area of over 100 hectares, while just one was more than 200 hectares. As far as thematic values are concerned, 48.65% have a low-quality value, 17.62% a high value, 16.35% a medium value, 13.32% a very low value and 4.07% a very high value. As regards surface, the very low value units make up 35.8% of the whole area, the low value units 40.29%, medium value 9.78%, high value 12.07% and very high value 2.06% of the total (Figure 7). The very low and low-quality units were scattered throughout the study area, although a certain concentration could be seen in the

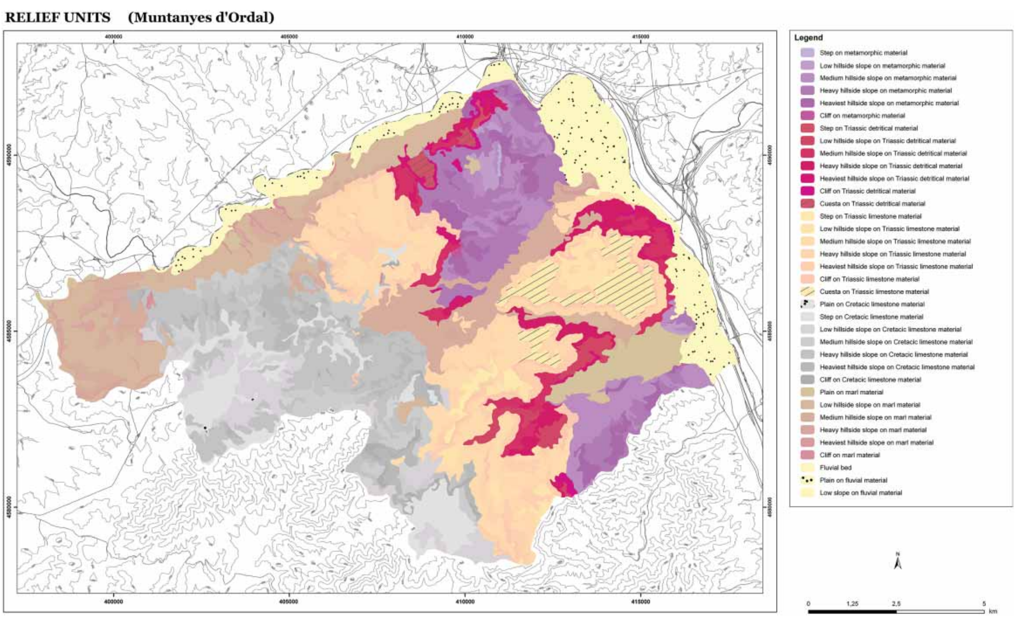

Figure 4. Relief units.

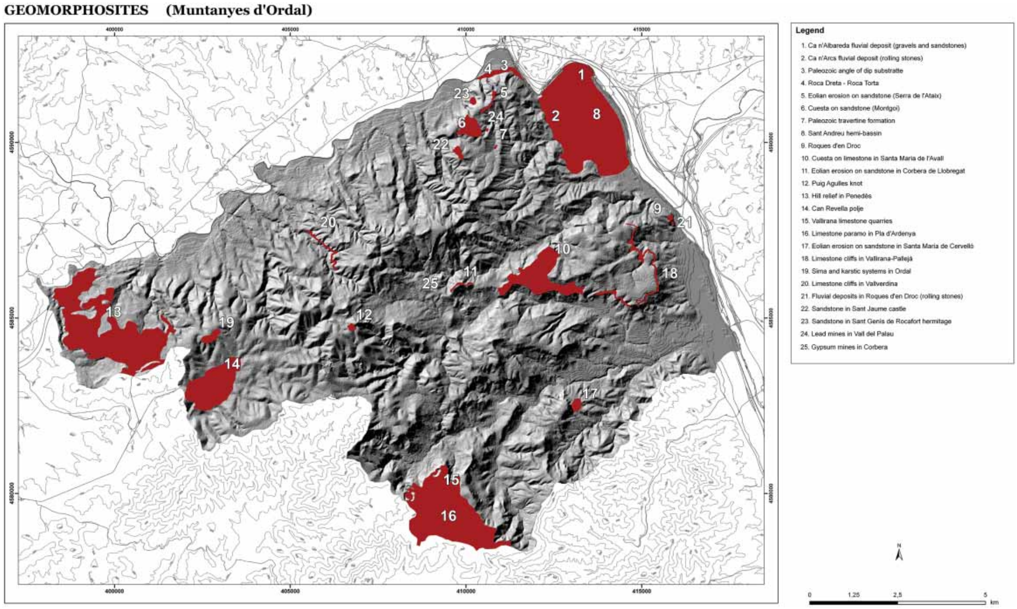

Figure 5. Geomorphosites.

central and north-eastern sectors; the medium-quality units had an erratic distribution that is difficult to define, while the high and very high-quality units were located in the northern, central and south-western areas, with small, separate groupings and a localized character.

From a cartographic perspective, five user-defined intervals are used, and these were made to coincide with the five nominal categories (very low, low, medium, high and very high). This type

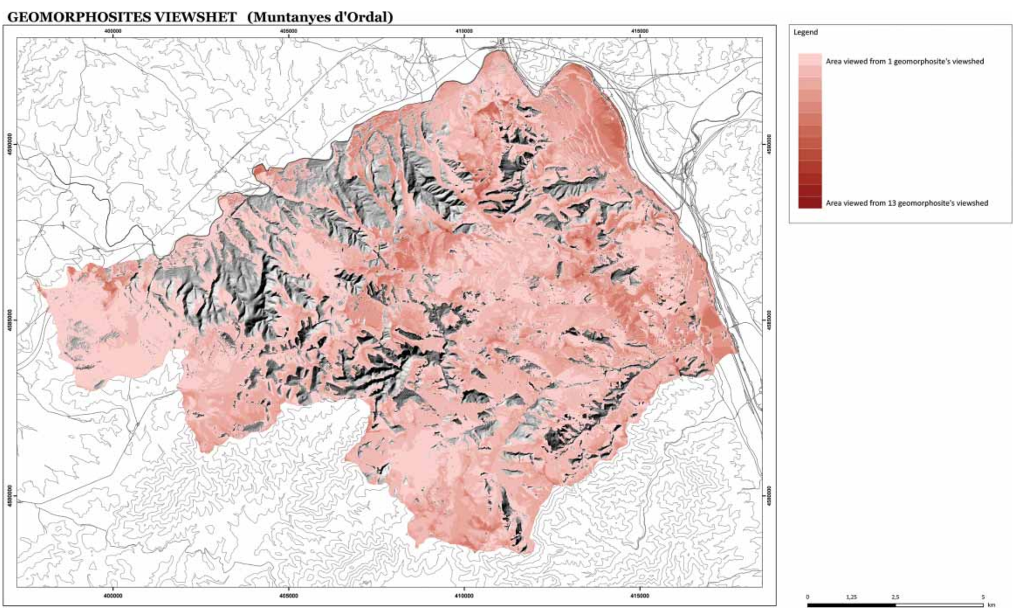

Figure 6. Viewshets established from geomorphosites.

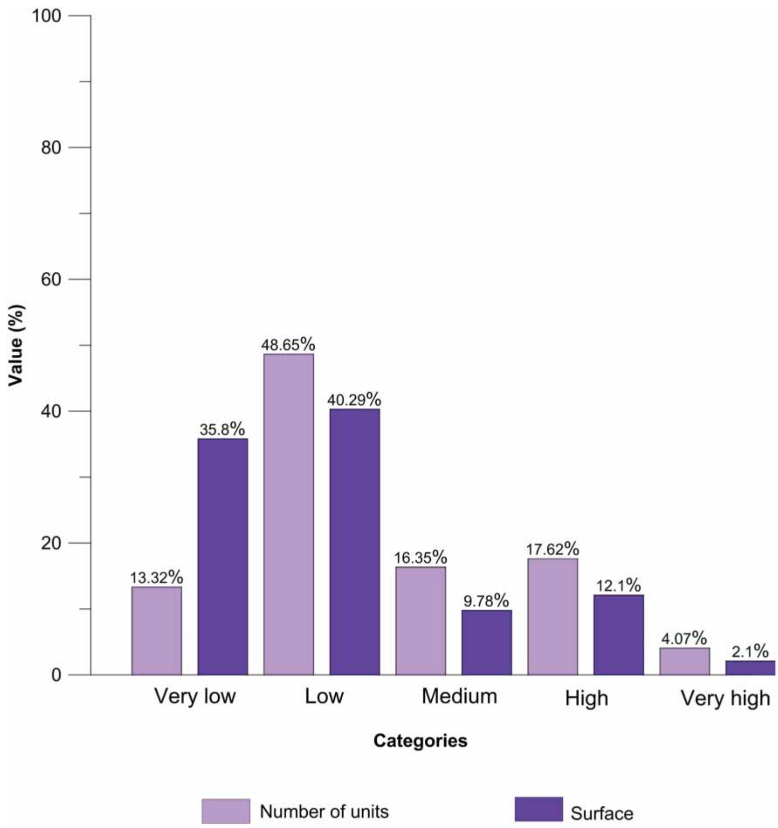

Figure 7. Relief values, from a landscape perspective. Nb: number of units and surface are related to the entire studied area.

of classification has a high degree of ambiguity that can only be corrected using the expertise of the mapmaker who set the categories (Slocum, McMaster, Kessler, & Howard, 2010). In this case, we considered the relief units and geomorphosites to be the main sources of information for the study, since the viewsheds (which are derived from the geomorphosites and, in turn, the relief units) focus on adding value to the land from which they can be observed. Hence the more geomorphosites observed, the more value they add. It can therefore be deduced that the maximum scores in the weighting of relief units and geomorphosites must coincide with high-quality values, with the very high values being reserved for those other locations from which it may be possible to observe one or more geomorphosites. Thus the values obtained were adapted to the five pre-established categories, in which the values 0 to 2 denote very low, 3 to 4 denote low, 5 medium, 6 to 7 high, and 8 and over very high.

5. Conclusions

This paper presents a methodology for mapping geomorphological values using landscape criteria. To this end extensive fieldwork was carried out in order to gather landform information under two headings: the general character of the area in which they are located, and the existence of elements which, by their very nature, are of singular value. Important scale discrimination criteria were applied in both cases depending on the size of the study area. The information obtained was entered into a geographic information system, which enabled a detailed thematic map to be produced. The variables analyzed were amalgamated by using weighted values and viewsheds. The results were classified into five quality levels (very low, low, medium, high and very high) and shown on an illustrative map at a scale of 1:25,000.

The method was applied in Muntanyes d'Ordal, a Mediterranean mountain area near Barcelona (Spain). The results obtained indicate a predominance of low and very low values (more than 75% of the whole), a significant presence of high and medium values (12% and 9.77%, respectively), and a small presence of very high values (2.06%) in the study area.

Finally, it should be noted that this type of experience is of great importance in the field of landscape evaluation and assessment, in the carrying out of environmental studies and particularly in territorial planning and organization. The methodology presented is of interest in these areas because it is easy and simple to apply and can therefore be implemented without difficulty in different land settings.

Software

Bentley MicroStation v8 and ESRI ArcGis 10 were used as the analysis platform for this project, and Grapher 8 for the production of Figure 7. Esri ArcGIS 10 was also used to design the maps.

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