MAPPING GEOMORPHODIVERSITY. CASE STUDY – BUCEGI MTS (THE SOUTHERN CARPATHIANS, ROMANIA

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Abstract. The present paper aims at developing a new type of map, namely the map of geomorphodiversity of the Bucegi Mts., an area that is representative for the Romanian Carpathians. Based on the inventory of geomorphosites and by the overlapping of several maps it was accomplished, for the first time, the geomorphodiversity map. The values obtained for this parameter are high, and they vary between 3 and 81. This operation has got a practical utility, with the purpose of developing geomorphosites in the touristic activity and their superior protection as a support for geomorphodiversity.

Keywords: geomorphosites, geomorphodiversity, Bucegi, Romania

1. Introduction

The term geomorphodiversity refers to "the critical and specific assessment of the geomorphological features of a territory, by comparing them in an extrinsic and in intrinsic way, taking into account the scale of investigation, the purpose of the research and the level of scientific quality" (Panizza 2009). One may consider that the complexity of geosites generates geodiversity (Gray 2004), while the diversity of the geomorphosites leads to geomorphodiversity.

Geomorphosites form multifunctional entities which represent a real network (Reynard et al. 2009), which may offer important data regarding geomorphodiversity, although it has a discontinuous and aleatory distribution in space. Thus, their didactic side develops, by the fact they can be studied in the place (in the nature, where they formed) and they can offer general information regarding the respective space geomorphodiversity. Yet, the evaluation of geomorphosites is not identical with that of geomorphodiversity. Thus, geomorphodiversity also knows a qualitative side of evaluation,

whereas geomorphosites are strictly evaluated quantitatively, depending on the quantifiable parameters (Kostrzewski 2011).

2. STUDY AREA

The Bucegi Mountains are situated in the eastern part of the Meridional Carpathians, between the Prahova Valley in the east and the Rucăr-Bran Corridor in the west. They are made of an arch of mountains having the shape of a horseshoe, opened in the south and fragmented in the central part by the Ialomita Valley, a strongly deep valley and presenting sectors which are different as appearance (gorges and depressionary basinets) (Ielenicz & Comănescu 2006). The maximum altitude is recorded at the Omu Peak (2505 m).

From the geological point of view there is a crystalline fundament and a gross mass of conglomerates overlaps on it (Velcea 1961). There are also patches of limestones and flysch. A varied range of geomorphosites developed starting from them, and they are important landmarks in establishing the geomorphodiversity within the area.

The relief of the analysed space is complex and diversified. We ennumerate the most important categories of geomorphosites which are found in the analysed space and which will be taken as a basis in determining geomorphodiversity (Ielenicz & Comănescu 2006): morphostructural elements (the sectors of structural abrupts; structural plateaus; structural thresholds on which waterfalls are developed), morphopetrographic elements (depressionary basinets, gorges, caves), ruiniform relief (fangs, needles, towers), morphoclimatic elements (alpine peaks, glacial complexes, karlings).

3. METHODOLOGY

In the next place of our demarche, we aim to show the way the geomorphosites' inventory may become a basis for the determination of geomorphodiversity and to propose a methodology of estimation for it. Up to present, no quantifying of this parameter was done worldwide. In accomplishing it, we also had in view the method of evaluating geodiversity (Serrano & Ruiz Flano 2007).

The geomorphodiversity map has been done in several stages:

The first stage investigated the geological conditions of the study area based on specialty literature and on the existing graphic and cartographic sources (geological and geomorphological maps, as well as aerial photographs). In this respect, the geological map has a significant relevance, because struc-

ture and petrography generate specific landforms that acquire value thorough the human perception (Comănescu & Nedelea 2010). This so-called geomorphosites lead to high values of geomorphodiversity. In order to correlate them with the geological conditions they were outlined on the geological maps.

At the base of the geomorphodiversity assessment lies the general geomorphological map (Demek et al. 2011), which was developed after several field trips undertaken with the purpose of making measurements and detailed mappings using a Garmin GPS receiver. The general geomorphological map, which was filled with additional data derived from aerial imagery (the flight of 2005), also gave us the possibility to make an inventory of the geomorphosites that can be seen in the study area.

In order to complete the database, we mapped all the geomorphosites and finally came up with a geomorphosite map.

By making a synthesis of the information collected in the previous stages we were able to compute the geomorphodiversity index based on the formula below:

$$Gmd = (\sum EgXn + Gm)/S$$

where Gmd = geomorphodiversity index; Eg = the number of landforms; n = the number of the genetic types of landforms; Gm = the number of geomorphosites; S = area (in sq. km)

A close attention was paid to the geomorphosites, which were taken into account twice, both in the first category (as landforms) and in the second one, in order to assign them an additional value. Thus, if two areas have the same number of landforms and the same typology, geomorphodiversity will be higher where the number of geomorphosites is higher.

The geomorphodiversity map is prepared by using the GIS techniques, which allow the overlapping of several thematic layers (geology, geomorphology and geomorphosites), and the cartographic algebra. For a greater accuracy and a higher level of detail, we used standard areas of 0.5 km^2.

4. RESULTS AND DISCUSSION

The values obtained for geomorphodiversity are dimensionless and they show the variety and diversity of the types of forms of relief, on surface units. The detailed mapping of all the relief forms, the correct setting of the genetic type in which these are included, as well as the complete inventory of geomorphosites (sometimes it is necessary to create a specialized data base) will contribute to the correct determination of geomorphodiversity. In

Table nr. 1 there are elements which describe geomorphodiversity (*Figure 1*), elements which were taken into consideration when calculating geomorphodiversity. As there are cartograms with a surface under 0.5 square kilometers (the surface considered to be the standard) comprised in the area taken into study, the values in these are not significant (due to the limited number of elements situated on a much reduced surface than the standard surface). Below, we will analyse only the valued obtained in those cartograms (18 cartograms) comprised integrally in the area taken into study, their numbering being done from left-up towards right-down.

By applying the formula of geomorphodiversity there were obtained values between 18 and 112, large amplitude between the minimum and maximum value, which led to the detaching of 5 classes of values: under 20 – very low, 20-40 - low, 41-60 - medium, 61-80- high, over 80- very high) (*Figure 1*).

The values under 20 (5, 56 %) are feebly represented in this area, but they can be much more present in other mountainous spaces where there isn't a diversity of the forms of relief. This cartogram is within the structural plateau of the Bucegi Mountains (regarded at regional scale). The values between 20-40 (38, 88%) present the highest weight from the entire analysed space, unfolding at regional scale on the same structural plateau like the first category *(Figure 1)*.

The diversity of the values obtained is due to the presence of a varied range of forms of relief (torrential organisms, erosion outliers, peaks, nival microdepressions), from among which some are geomorphosites.

The third class of values (between 41-60) holds a weight of 22, 22%, the cartograms included in this class being situated both at the border of the structural plateau and within the abrupt *(Figure 1)*.

The class of values between 61-80 have got a weight of 16,67%, being the values which appear in two situations: either within the abrupt, where there is a varied range of forms and processes, or on the structural plateau, where the most important geomorphosites of the area taken into study are situated: the Sphinx and Babele *(Figure 1)*.

The combination between the two situations (the presence of the abrupt and the existence of geomorphosites) determines the highest values (over 80). These hold a weight of 16, 67% and they show high values, both for intrinsic and extrinsic geomorphodiversity *(Figure 1)*.

Geomorphodiversity must be regarded dually, depending on the scale we relate to (Panizza, 2009): extrinsic geomorphodiversity (at global or regional scale) and intrinsic (at regional and local scale). Thenceforth, we will

accomplish (*Table 1*) an analysis regarding the quantitative presence of the two types of geomorphodiversity: extrinsic and intrinsic.

Nr. Cartogr.	Elements	Nr. Cartogr.	Elements	Nr. Cartogr.	Elements
1	5 torrential organisms 1 structural abrupt 2 erosion witnesses 3 nival microdepressions 1 structural plateau	7	1 structural abrupt 2 torrential organisms 3 erosion witnesses 1 structural plateau	13	1 structural abrupt 1 torrential organism 2 erosion witnesses
2	4 torrential organisms 1 structural abrupt 1 erosion witness 3 nival microdepressions 1 structural plateau	8	1 geomorphosite 4 torrential organisms 1 structural abrupt 4 erosion witnesses 1 peak 5 nival microdepressi-ons 1 structural plateau	14	1 geomorphosite 5 torrential organisms 1 structural abrupt 7 erosion witnesses 1 nival microdepressi-on 1 structural plateau
3	3 torrential organisms 1 erosion witness 3 nival microdepressions 1 structural plateau	9	3 torrential organisms 5 nival microdepressi-ons 1 structural plateau	15	1 torrential organism 1 nival microdepressi-on 1 structural plateau
4	1 geomorphosite 3 torrential organisms 1 peak 1 nival microdepression 1saddle 1 structural plateau	10	2 geomorphosites 3 torrential organisms 1 erosion witness 4 nival microdepressi-ons 1 structural plateau	16	1 geomorphosite 2 torrential organisms 2 erosion witnesses 1 peak 1 nival microdepres-sion 1 structural plateau
5	2 geomorphosites 5 torrential organisms 1 peak 1 nival microdepression 5 saddles 1 structural plateau	11	1 geomorphosite 1 torrential organism 5 erosion witnesses 2 nival microdepressi-ons 1 saddle 1 structural plateau	17	2 geomorphosites 1 torrential organism 2 erosion witnesses 2 saddles 1 structural plateau
6	1 geomorphosite 2 torrential organisms 1 peak 5 saddles 1 structural plateau	12	2 geomorphosites 1 torrential organism 1 erosion witness 1 nival microdepres-sions 1 saddle 1 structural plateau	18	1 geomorphosite 3 torrential organisms 3 erosion witnesses 4 peaks

Table 1. The elements which describe geomorphodiversity

5. Conclusion

Geomorphodiversity must be regarded at global and especially at regional level, being the result of the conjugation in time and space of external and

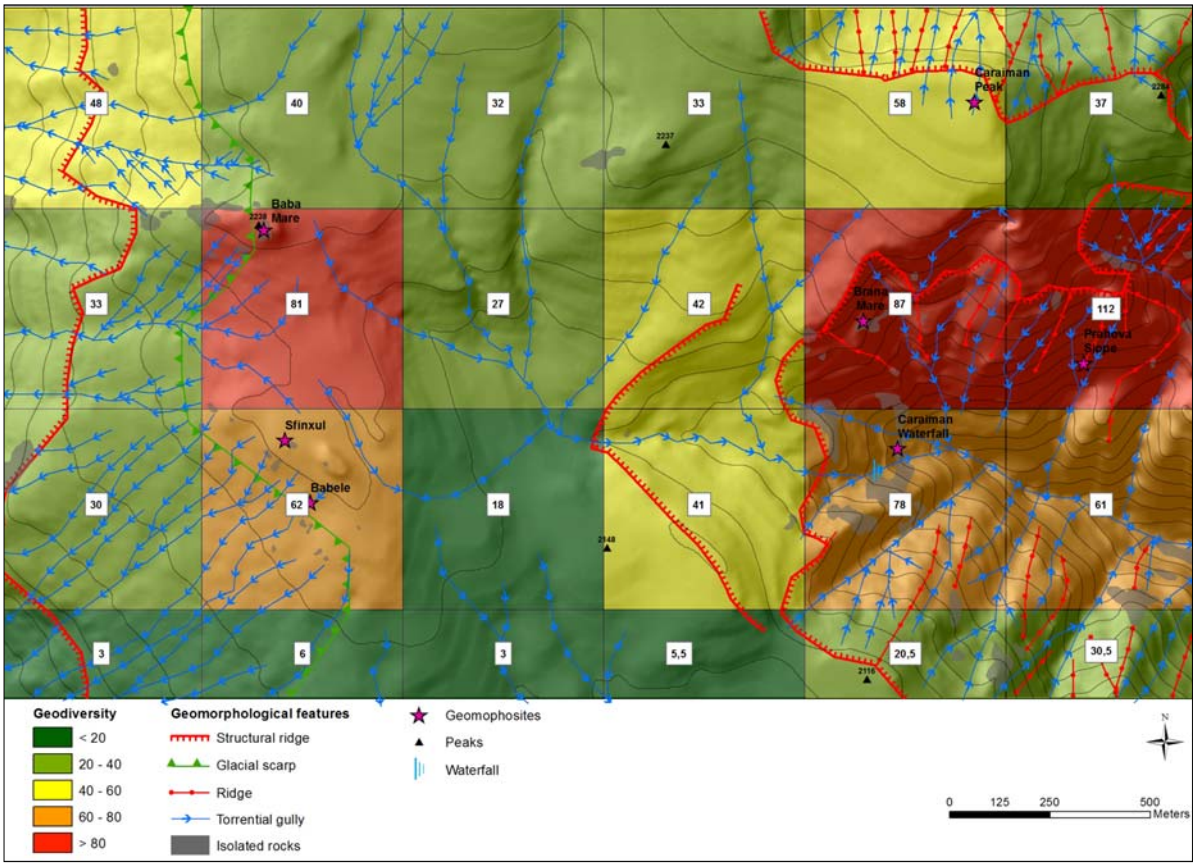

Figure 1. The map of geomorphodiversity (Comănescu& Dobre 2012, modified)

internal agents. In the formula proposed, an important value is given to geomorphosites, as these represent most suggestively the relationship between the form of relief and touristic activity, by the perception the tourists give – the value, which may be – aesthetic, cultural, scientific and economic. Geomorphodiversity can become an important instrument in the process of geoconservation, in managing geotouristic products, in territorial planning. Quantitative evaluation of geomorphodiversity represents a step forward regarding the optimal use of the touristic space.

As a future problem, we will have in view the calculation of geomorphodiversity on certain representative paths, the values obtained being extremely important in creating thematic paths and geotouristic specificity paths. The geotouristic map presented can be enriched, for the first time, with quantitative elements, besides the previous parameter adding others, as the time of transit for some paths, the declivity, the difficulty degree.

Acknowledgements to all those who supported the accomplishment and publication of this article, within the project: (*Inventoring, Evaluation and Mapping of Geomorphosites. Case studies: the Dobrodjea Plateau and the Southern Carpathians*, project manager Laura Comănescu, financed by CNCSIS/ NURC, category IDEI.

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