A GIS-BASED ASSESSMENT OF GEODIVERSITY IN THE MARAMURES MOUNTAINS NATURAL PARK. A PRELIMINARY APPROACH

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ABSTRACT
Assessing geodiversity in a natural protected area is of increasing importance as it stands for the abiotic setting for biodiversity. Although, this concept has been tackled in different scientific papers from different viewpoints based on different variables of the abiotic environment, the current paper is aiming to propose an integrated GIS-based methodology relying on both quantitative and qualitative approaches. The authors are using a wide range of spatial data at various spatial and temporal scales (topographic, soil, geological maps etc.), climatic parameters and field surveys in order to develop a comprehensive methodology able to assess geodiversity in the Maramures Mountains Natural Park. The current research represents the starting point for the development of a geodiversity index in order to estimate the diversity of the abiotic elements in the study area. The expected results will help establishing the best connections with the biotic environment (biodiversity) as well as the cultural heritage, as essential goals in the management of a natural protected area.

Keywords*: GIS, geodiversity assessment, protected areas, Maramures Mountains Natural Park*

INTRODUCTION

The quantification and evaluation of geodiversity constitute a relatively new approach in representing, at different scales, landscape units. The concept of geodiversity was originally introduced in the 90's in Tasmania and Australia and furthermore more extensively used across Europe in the last decade, especially after incorporating this concept in the legislation of some countries (e.g. Spain, UK).

Originally, geodiversity was identified as synonym to "*abiotic diversity*" (geological, geomorphological, hydrological and pedological) in order to be separated from biological diversity or particularly to "*geological diversity*" (Duff, 1994; Serrano et al., 2009; Pellitero, 2011). Some of the recent studies still use this restricted approach even if over the last years the term acquired a wider significance, as defined by Stanley (2003) *"the link between people, landscape, culture - the variety of geological environments, phenomena and processes that determine landscape, rocks, minerals, fossils and soils - providing support life on Earth ... biodiversity as part of geodiversity"* or Gray (2004) *"natural diversity of geological, geomorphological and soil characteristics. It includes their assemblages, relationships, properties, interpretations and their systems*" or Kozlowski (2004) who broadens this concept to considering as equal contribution the effect of human-induced activities on geodiversity and natural processes.

So far, apart from the theoretical approaches, the geodiversity assessment methodology has been enriched with several case-studies developed in different areas with particular landscape features and at different spatial scales: the Iberian Peninsula (Benito-Calvo et al., 2009; Serrano and Ruiz -Flaño 2007; Serrano and Ruiz –Flaño, 2009; Serrano et al., 2009; Serrano et al., 2011 etc.) Poland (Alexandrowicz and Kozlowski 1999; Kozlowski, 2004), Finland (Hjort and Louto, 2010) etc.

In the Romanian scientific literature, the concept of geodiversity is at its beginning, being mainly restricted to approaching *'geological diversity'*, thus being tacked by a small group of researchers.

Although there is a strong interconnectivity between biodiversity and geodiversity (a higher geodiversity triggering an increased biodiversity), the Romanian legislation on natural protected areas almost exclusively deals with preserving biological diversity (Năstase, 2012). Under the given circumstances, since both geodiversity and biodiversity are threatened by degradation, mainly as a result of human-induced activities (erosion, rock exploitation, agriculture, urban development, tourism pressure etc.), assuming proper geoconservation measures is highly recommended. Once identified, in order to guarantee the proper management of the natural heritage, these measures must be correlated with the biodiversity conservation and together must be equally taken into consideration in the management plan of the protected areas.

THE STUDY-AREA: MARAMUREŞ MOUNTAINS NATURAL PARK

The current research mainly focuses on Maramureş Mountains Natural Park that overlaps the highest mountain massif located in the central part of the Carpathian Chain ($24^0$30'00" long. E and $47^0$48'00" lat. N), at the border of Romania with Ukraine (fig.1).

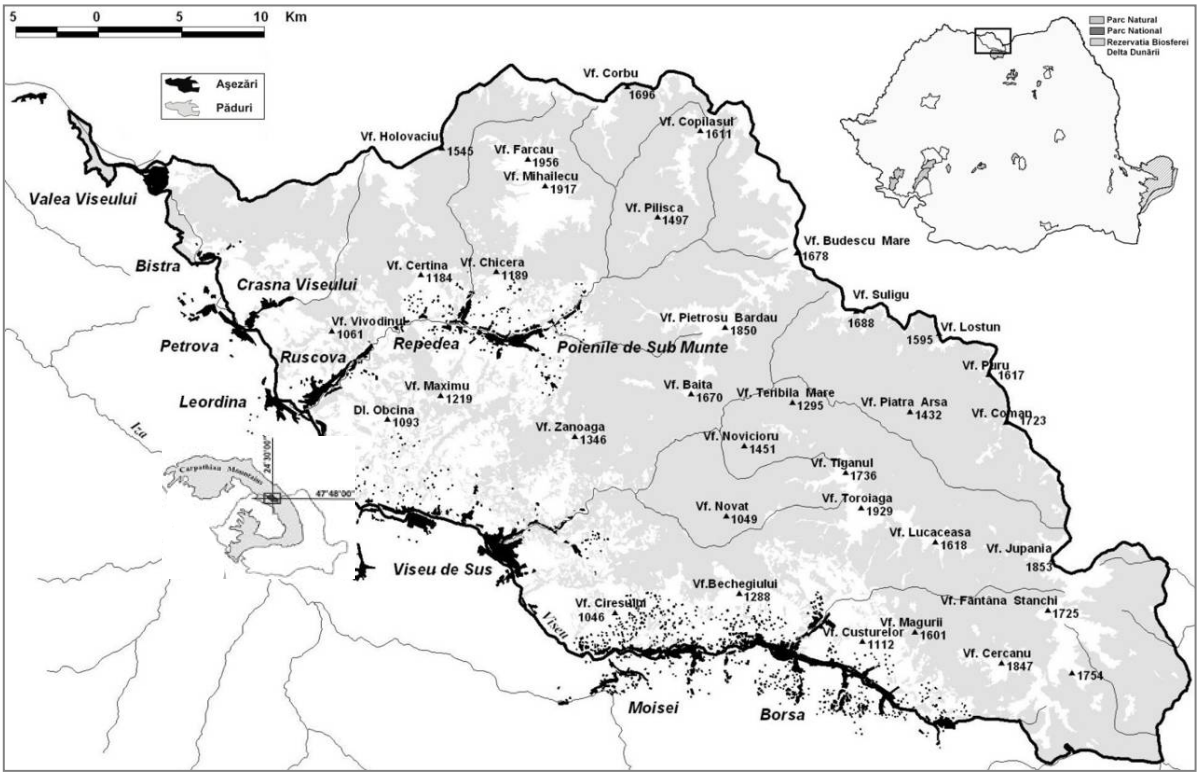


Figure 1. Location of Maramureş Mountains Natural Park in Romania and in the Carpathian Chain

Maramureş Mountains Natural Park is a relatively recent declared (2004) natural protected area, under the *Category V IUCN – Protected Landscape - Natural Park*, having as main environmental features for its designation: the specific landscape of mountains covered by forests alternating with alpine meadows, the presence of flora and fauna specific for the Carpathians and the traditional lifestyle (Năstase et al., 2010; Bălteanu et al., 2011). Moreover, 70% of the Park area – except the inner-city of the localities within – has been included in European Network – Nature 2000.

The Maramures Mountain Natural Park is the biggest from major protected area in the Romanian Carpathians covering a surface of 133,354 hectares and gathering almost 89.000 inhabitants (2010). Its economy has always been related to agriculture, especially in terms of cattle breeding on the rich sub-alpine pastures and meadows, forest (coal) harvesting and

mining exploitation which is currently affected by restructuration processes and the closing of quarries.

METHODOLOGY AND DATA

A comprehensive approach of natural protected areas in terms of adopting the proper conservative and management measures requires the complex assessment of both geodiversity and biodiversity as complementary environmental indicators

The current research represents the preliminary approach of a composite research aiming at developing a *geodiversity index* able to estimate the variety of the abiotic elements in the Maramureş Mountains Natural Park. Therefore, the authors proceed to estimating the geodiversity of the study-area through the analysis of the abiotic elements based on the methodology developed by Serrano and Ruiz-Flaño (2007) which was considered as the starting point of the study. Furthermore, based on this analytical approach, the methodology is to be extended and improved with a qualitative approach useful in developing the geodiversity index.

Therefore, a wide range of spatial data at various spatial and temporal scales we used in order to develop a comprehensive methodology able to assess geodiversity in the Romanian protected areas, with a special focus on the Maramureş Mountain Natural Park. The study consisted in cross-referencing the bibliographical literature (mainly geographical, geological etc.), spatial data (GIS processing) and field surveys in terms of mapping and processing the collected data. Furthermore, the authors assessed the geodiversity elements (geology, relief units, slopes etc.) based on geomorphological units for estimating the relevant parameters.

RESULTS AND DISCUSSIONS

The assessment of geodiversity in the Maramureş Mountain Natural Park was undertaken relying on the analysis of the main abiotic elements: geology, geomorphology, hydrology, soils, and climate considered as input data.

From ***geological*** point of view, the study-area is characterised by a wide variety of geological elements: metamorphic rocks of the Proterozoic-Paleozoic period, magmatic rocks of Upper Miocen age and sedimentary rocks accumulated during the Middle Jurasic and lower Cretacic era.

The ***relief*** is characterized by mountain units developed mainly on the Crystalline–Mesozoic strip separated by a succession of depressionary basins, valleys and glacises. The highest part of the Maramureş Mountains rise up to 1000-1800 m, reaching the highest point in the Farcău Peak (1957 m).

The contact between the mountain and the depressionary areas is represented by a glacis step, namely the Vişeu Glacis (400 – 750 m) which displays steep slopes and cuestas between Borşa and Ruscova localities. The mountain and hilly slopes are regularly affected by gulling and solifluxion processes in upper parts and landslides in the lower parts.

Out of the combination between the geological elements, main geomorphological features (slopes, declivity) have resulted the ***geomorphological map*** which represents a valuable indicator in terms of identifying the abiotic richness and geomorphosites of Maramureş Mountains Natural Park (Fig. 2 and 3).

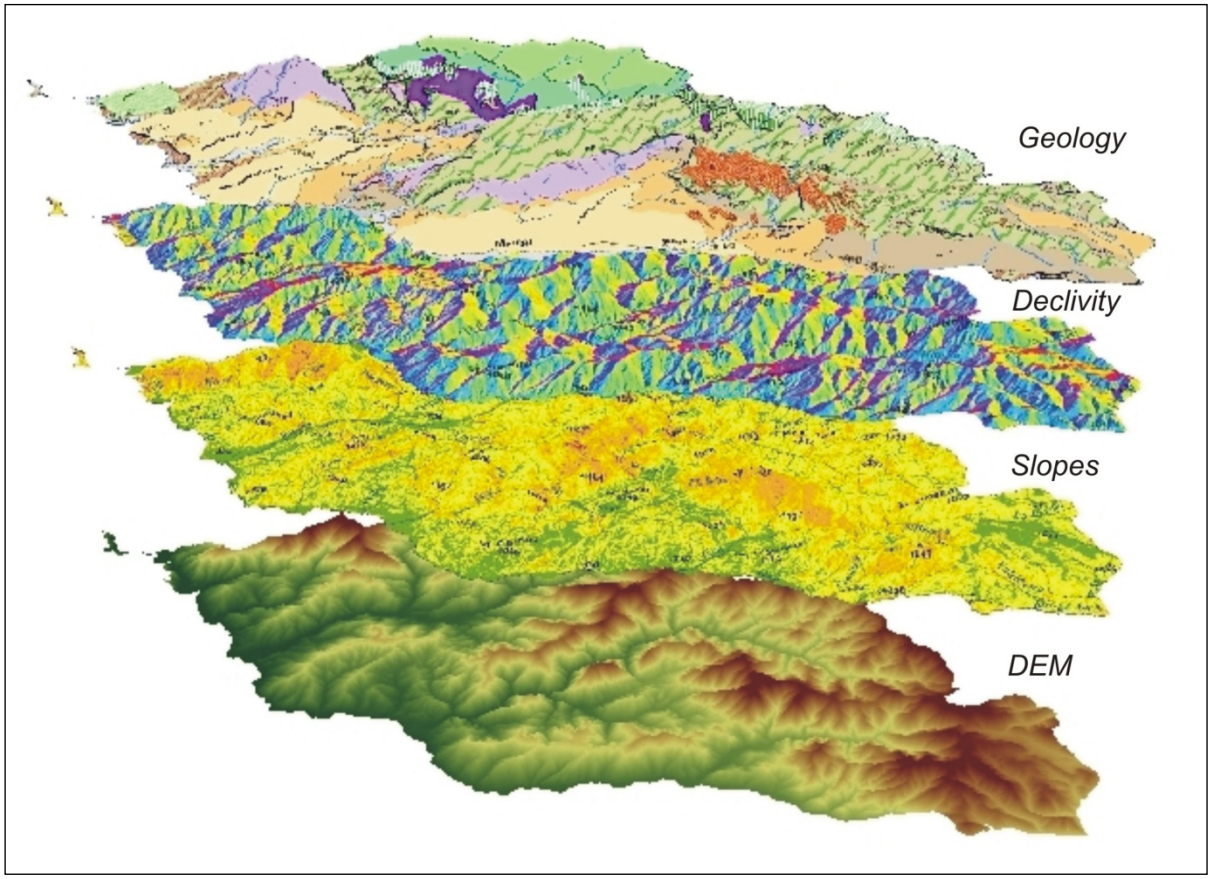


Figure 2. The main abiotic elements (geology, declivity, slopes and DEM) used for the geomorphological map

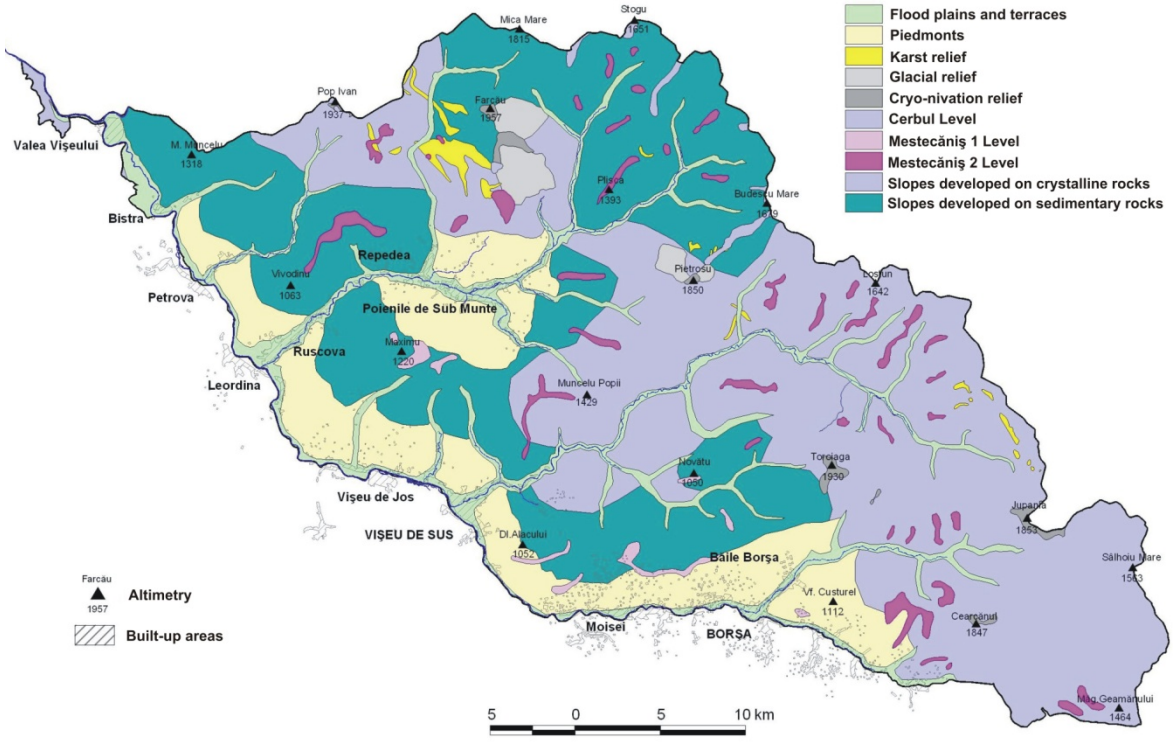
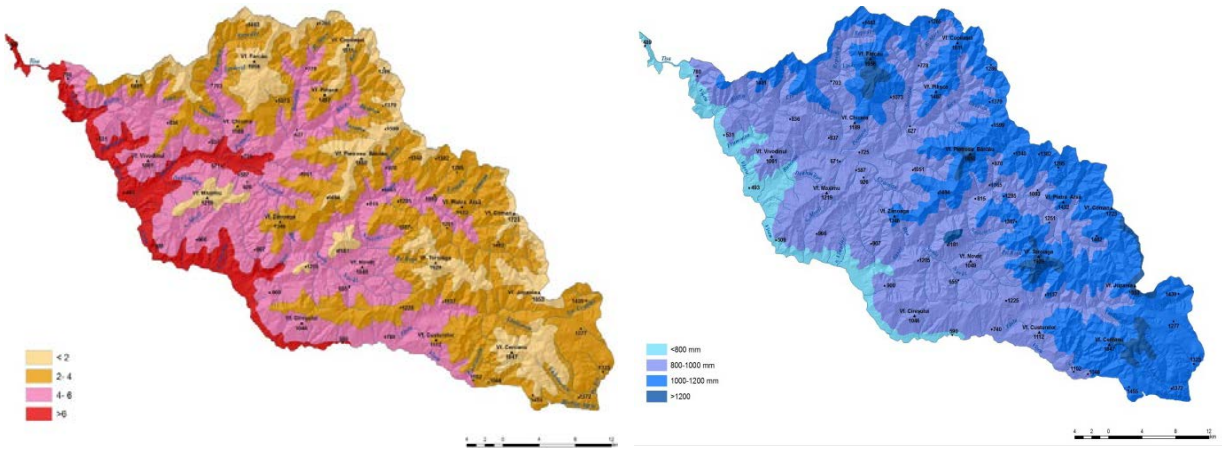


Figure 3. The geomorphological map

Additionally, other environmental elements were added in order to further investigate the geodiversity of the study-area: soils and climate. The ***soils*** are predominantly *Cambisoils* in the areas covered by forest vegetation, *Spodisoils* and *Litosoils* are developed in the highest areas on the main ranges and *Aluviosoils* in the main floodplain areas.
The analysis of the main ***climatic*** elements (mean annual temperature and mean annual precipitation amounts) could also have an important contribution to the evaluation of geodiversity.



a **b**

Figure 4. Mean annual temperature (a) and mean annual precipitation amounts (b)

The mean annual temperature values range between 4-6 ^{0}C in the lower depressionary areas and valley corridors and 4-2 ^{0}C on the mountain heights. Precipitation amounts totalise between 900-1000 mm on the eastern slopes up to 1200-1400 on the western slopes (Fig. 4).
As a result, the variety of lithology, geological structures, relief forms, and soils associated with the natural dynamics triggered by the temperate-continental moderate climate, with Baltic influences and the intense and continuous human intervention describes the wide geodiversity of the Maramureş Mountains Natural Park.
The current study on the geodiversity assessment in the Romanian protected areas with a special focus on Maramureş Mountains Natural Park in relation to biodiversity is essential in identifying and defining the most important conservative measures to be considered in management plan of this protected area. Therefore, establishing the relationship between geodiversity and biodiversity would provide valuable future predictions through GIS-based modeling techniques.
As a result, the outcomes of the present paper could constitute an important starting point for further assessments on geodiversity in terms of sustainable management. The results can be used by the management authority of this natural protected area as an important tool for the establishment of areas with different coping capacity to natural or human-induced pressures.

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