INVENTORY AND ASSESSMENT OF GEOMORPHOSITES IN THE UPPER ARGEȘ HYDROGRAPHIC BASIN (FĂGĂRAȘ MOUNTAINS – SOUTHERN CARPATHIANS, ROMANIA)

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ABSTRACT

The unanimously accepted global definition states that geomorphosites are landforms that gain value due to human perception. This study aims to conduct an inventory of the most important and representative geomorphosites in the upper Argeș hydrographic basin and to assess using own method, which is adapted to Romania's specific geographical features.

The analysed region is located in the central area of the Făgăraș Mountains (which hold Romania's highest peak, 2544 m). Argeș is the outcome of the merger of two tributaries: Buda and Capra. It features a lithological diversity and the effects of the different geomorphological agents that have been active over time, which has resulted in a wide range of geomorphosites (glacial, periglacial, petrographic, fluvial etc.), some of which are representative nationally.

The method developed in 2010 equally considers *scientific value* (paleogeographic interest, representativeness, rareness, integrity, degree of scientific knowledge, use in educational purposes, ecological value, diversity), *aesthetic value* (visibility, space structuring, colour contrast, level difference, landscape framing), *cultural value* (cultural, historical, religious characteristics, iconographic / literary representations, festival/cultural events, symbolic value), *economic value* (accessibility, infrastructure, yearly visitors number, number of types and forms of use, economic potential), and *management and use* (preservation degree, protected sites, vulnerability / natural risks, the intensity of use, the use of aesthetic, cultural and economic value, relationship with planning policies).

Keywords: geomorphosites, inventory, assessment method, Argeș Valley, Southern Carpathians, Romania

INTRODUCTION

Geomorphosites are landforms that have been assigned a value due to human perception. These values can be: scientific, aesthetic/scenic, cultural and economic [8] [11]. Over time, the importance of geomorphosites has been recognized within the geomorphological landscape and for its superior use in tourism activity.

For the evaluation of geomorphosites, there are numerous and different methods in the scientific literature, adapted to the proposed purpose and the analysed area [13]. The most important and used methods developed in literature are: *the method of evaluating the tourist value of geomorphosites* designed by J. P. Pralong in 2005 [10], the *method developed* by P. Coratza and C. Giusti in 2005 [4]; *the method proposed* by V. M. Bruschi

and A. Cendrero in 2005 [1]; the *method developed* by N. Zourous in 2005 [16]; the *method proposed* by E. Serrano and J. J. Gonzales Trueba in 2005 [15]; the *method developed* in 2007 by E. Reynard et al. [12]; the *method proposed* in 2007 by P. Pereira [9]. As stated in previous studies [3] [13], each of these methods presents a series of strengths and weaknesses depending on the objectives of the evaluation and the geographical area for which it was designed and applied.
The newest method of evaluating geomorphosites belongs to Reynard et al., (2016) [14] who, based on previous experience [12], considers that evaluation is part of a laborious process, including selection, inventory, capitalization by stakeholders and their use. The selected geomorphosites must be spatially and temporally representative [14].
The method we developed [3] aims to be adapted to the geographical particularities of the Carpathian space, to include a wider range of parameters taken into consideration and implicitly, a high degree of objectivity. It was applied in the previous study, for Ponoare protected area, which has a typical karst relief [3]. The objective of this study is to apply the proposed method in an area with other morphogenetic characteristics and another typology of geomorphosites. Our final approach is to validate and calibrate the method, comparing the results obtained for different types of geomorphosites.

STUDY CASE

The analysed area is located in Făgăraș Mountains (Southern Carpathians), which has the highest altitude in Romanian Carpathians: Moldoveanu Peak (2544m) and Negoiu Peak (2535 m).
Argeș basin is bounded by Făgăraș Ridge to the north and by Arefu sub-mountain Depression in the south (mostly on the 800 m level curve) (Figure 1). From the administrative point of view, it belongs entirely to Argeș county [6].

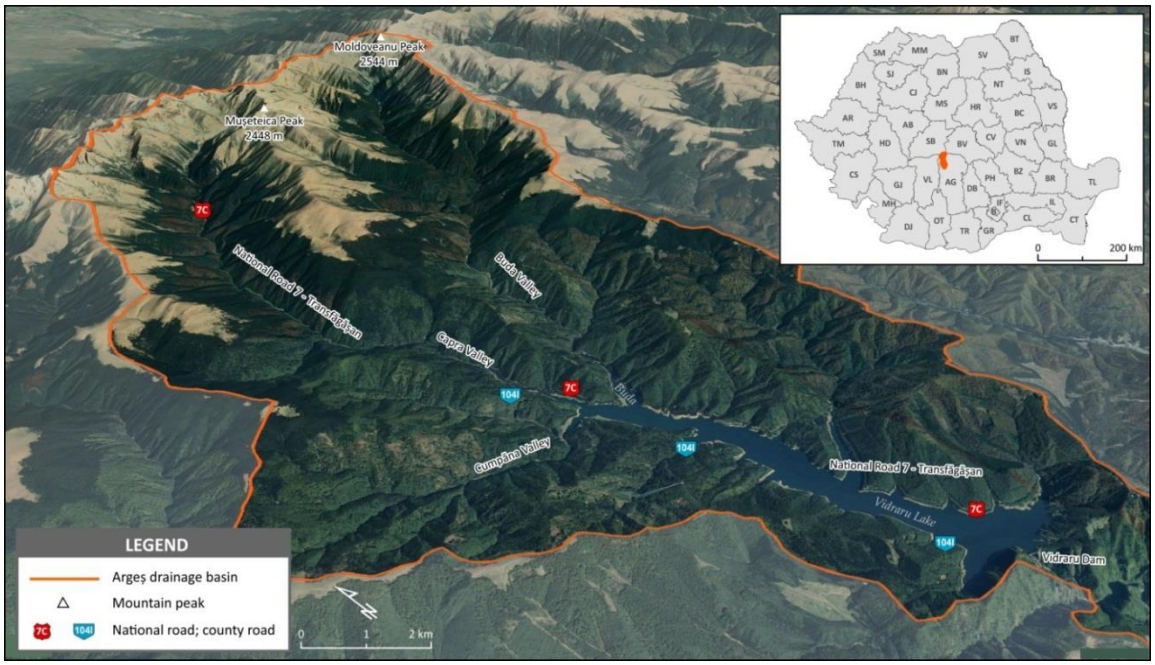

Figure 1. The geographical position of the upper Argeș hydrographic basin in Romania and Southern Carpathians

Argeș Valley in the mountainous (upper) sector is formed by the confluence of two tributaries: Capra and Buda, which are made at the end of the Vidraru artificial lake. In this sector, the course of Argeș has a length of 37 km [6].
The geographical location determines an alpine, subalpine and mountain-forest morphology, in which the relief steps decrease in altitude from north to south [6].
From a geological point of view, it is the largest Carpathian crystalline unit [5]. It consists of gnais and paragnais, micaceous schist, amphibolite and crystalline limestone [5]. Based on the varied tectonic-structural conditions, mosaic petrography has identified the genesis of various landforms, many of which are considered geomorphosites [7]. Thus, in gnais there were formed sectors of gorges (Argeșului Gorge), on crystalline shale residual reliefs of scree, needles or rocks with special shapes (Revolverul Cliff, Dragons Window Cliff) formed predominantly by periglacial processes and gorges (Buda Gorge). On the limestones was developed a ruiniform relief, with ridges, needles and towers (Râiosului Needles, Râiosu- Muşeteica Ridge), with screes, karren fields, sinkholes, gorges (Mușeteica) and karst springs [7].
Along with the rock, different modelling systems (glacial, periglacial, fluvial) have been imposed over time, all of them generating different types of geomorphosites. The most typical for this area are the glacial ones: the circuques (Capra, Călțun, Buda, Râiosu), Capra waterfall developed on a glacial threshold, the glacial karling (Arpășel), many of them later modelled in the periglacial system.
Within the present work, 18 representative geomorphosites for the alpine Carpathian area were identified, inventoried and evaluated, as genesis, typology and human use (Table 1, Figure 2).

Table 1. Geomorphosites from upper Argeș hydrographic basin

Name	Origin	Type
Argeșului Gorge	fluvial	linear
Stan Valley	fluvial	linear
Capra Cirque	glacial	area
Capra Waterfall	glacial	punctual
Capra Moraine	glacial	area
Călțun Cirque	glacial	area
Buda Gorge	fluvial	linear
Buda Cirque	glacial	area
Revolverul Cliff	periglacial	punctual
Dragons Window Cliff	periglacial	punctual
Mușeteica – Râiosu Ridge	karst	linear
Mușeteica Gorge	karst	linear
Izvorul Moldoveanu Valley	tectonic	linear
Moldoveanu Peak	morphological	punctual
Arpășelului Karling	glacial	linear
Arpașul Mic Peak	morphological	punctual
Vânătoarea lui Buteanu Peak	morphological	punctual
Râiosu Cirque	glacial	area

METHODOLOGY

The proposed methodology [2] [3] (Figure 3) follows several stages, according to most studies in the literature. Thus, the first stage consists in identifying and locating the

geomorphosites considering both the geographical, geological and related bibliography (history, biology, ethnography) as well as their mapping on topographic maps, aerial images and through field trips.

Figure 2. The most important geomorphosites in upper Argeș hydrographic basin (A. Capra Cirque, B. Capra Waterfall, C. Moldoveanu Peak, D. Călțun Cirque, E. Capra Moraine, F. Revolverul Cliff, G. Dragons Window Cliff, H. Argeșului Gorge)

Table 2. The criteria and scores proposed for evaluating geomorphosites [3]

Scientific value *(Sci)* – 20 p	Scenic value *(Sce)* - 20 p	Cultural value *(Cult)* -20 p	Economic value *(Ec)* - 20 p	Management and use *(Mg)* - 20 p
paleogeographic interest -3p	visibility – 4p	cultural characteristics -4p	accessibility -4p	preservation degree -4p
representativeness-2p	space structuring – 4p	historical characteristics -4p	infrastructure-4p	protected sites -3p
rareness – 2p	colour contrast - 4p	religious characteristics - 4p	yearly visitors number -4p	vulnerability/ natural risks - 3p
integrity -2p	level difference-4p	iconographic/ literary representations - 2p	number of types and forms of use (inclusively touristic) -4p	the intensity of use - 4p
degree of scientific knowledge -3p	landscape framing-4p	festivals/ cultural events -2p	economic potential (incomes) -4p	the use of aesthetic, cultural and economic value -3p
use in educational purposes - 3p		symbolic value - 4p		relationship with planning policies-3p
ecologic value-3p				
diversity-2p				

In the second stage, based on the geomorphological map, the geomorphosites are located and inventoried using the existing sheet in the specialized literature [10], with adaptations

related to the geomorphological and human use characteristics of the analysed area [2] [3]. Subsequently, the evaluation of the geomorphosites takes place based on the criteria included in the Table 2 [3].
Their total value is calculated according to the formula:

$$Vtot = (Vsci + Vsce + Vcult + Veco + Mg)/100 \quad (1)$$

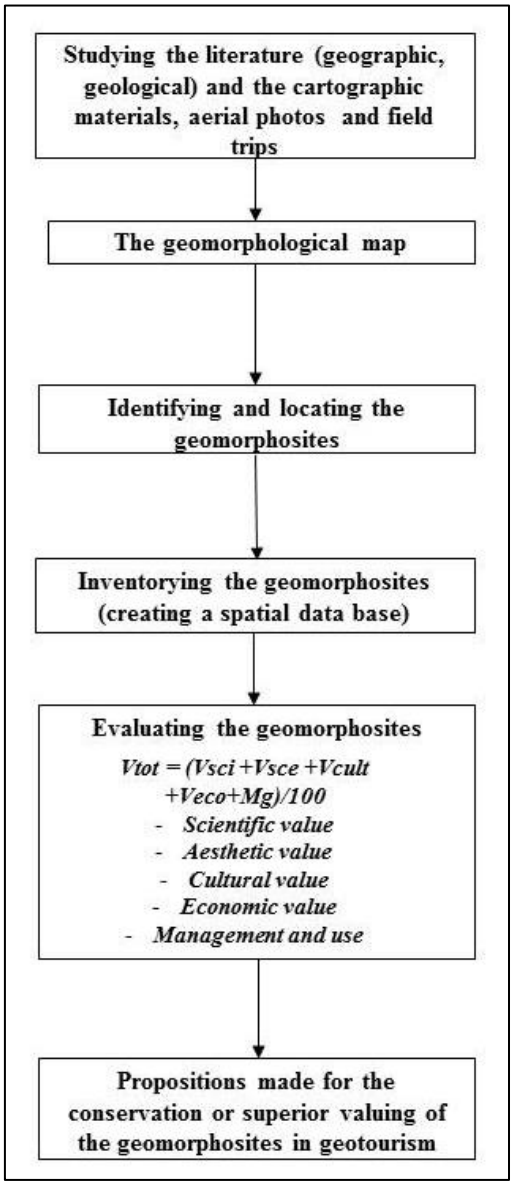

Figure 3. The stages of studying geomorphosites [2] [3]

As can be seen in Table 2, all the criteria received an equal weight (20 points), because the evaluation does not aim to highlight certain values of the geomorphosites. The sub-criteria that make up each criterion have values between 2 and 4, depending on the number of sub-criteria and their importance. For each of these, a score between 0 (the minimum value) and the maximum value to the respective criterion will be granted according to the table. The scale of assessment is quite large and allows an objective evaluation, being able to undergo adaptations depending on the area studied and the analysed geomorphosites [3]. The sum of the scores obtained for each criterion is realized, and the

value is divided to 100. It was considered necessary to make this reduction per unit in order to facilitate the comparison with the other methods used in the specialized literature [3].

RESULTS AND DISCUSSION

The highest total values obtained (Vânătoarea lui Buteanu Peak - 0.75, Capra Waterfall - 0.71, Moldoveanu Peak - 0.71, Capra Cirque - 0.70) (Table 3) belong to the geomorphosites that are included in or near Capra glacial complex, which is due to higher accessibility and the greater number of tourists who visit it, but also the existence of numerous studies that highlight their scientific value. The lowest total values (Table 3) have a series of less known and studied geomorphosites that have a more difficult access (Izvorul Moldoveanu Valley- 0.51, Mușteica Gorge -0.53, Călțun Cirque-0.53, Râiosu Cirque -0.54, Buda Gorge-0.54)

Table 3. The evaluation of geomorphosites' value by the proposed method

Geomorphosites	Scientific value	Aesthetic value	Cultural value	Economic value	Management and use	Total
Argeșului Gorge	15	18	2	17	12	64/0.64
Stan Valley	16	16	1	14	11	58/0.58
Capra Cirque	17	19	2	19	13	70/0.70
Capra Waterfall	17	18	2	18	16	71/0.71
Capra Moraine	15	16	1	17	12	61/0.61
Călțun Cirque	14	18	0	9	12	53/0.53
Buda Gorge	14	17	0	11	12	54/0.54
Buda Cirque	15	17	0	11	14	57/0.57
Revolverul Cliff	15	19	0	8	13	55/0.55
Dragons Window Cliff	17	19	1	10	13	60/0.60
Mușeteica – Râiosu Ridge	16	18	1	9	13	57/0.57
Mușeteica Gorge	14	17	0	10	12	53/0.53
Izvorul Moldoveanu Valley	14	16	0	9	12	51/0.51
Moldoveanu Peak	18	20	3	12	18	71/0.71
Arpășelului Karling	17	19	1	10	18	65/0.65
Arpașul Mic Peak	18	19	1	10	16	64/0.64
Vânătoarea lui Buteanu Peak	18	19	2	18	18	75/0.75
Râiosu Cirque	15	17	0	11	11	54/0.54

For the scientific value it can be observed that the highest values - 0.18 were calculated for Moldoveanu, Arpașul Mic and Vânătoarea lui Buteanu peaks (recognized for the degree of scientific and didactic knowledge, representativeness, integrity and partially use for didactic purposes), while the lowest values - 0.14 are held by the Călțun Cirque, Buda Gorge, Mușeteica and Izvorul Moldoveanu Valley (without a special representation or with a different degree of vulnerability).

For the aesthetic value were obtained the highest values, but we must note that it is the most subjective of the categories. The geomorphosites in Făgăraș attract tourists both for the viewpoints they offer as well as for the level difference, the colour contrast or the geomorphological landscape as a whole. The most important ones from this point of view are: Moldoveanu Peak-0.20, Capra Cirque-0.19, Revolverul Cliff-0.19, Dragons Window

Cliff -0.19, Arpășelului Ridge -0.19, Arpașu Mic Peak -0.19 and Vânătoarea lui Buteanu Peak-0.19. For the aesthetic value the smallest difference of values between 0.16 and 0.20 is recorded.

Considering the location of the geomorphosites in the mountain area, the relief with steep slopes and level differences of over 1000 m and the accessibility of recent and isolated data for some geomorphosites, these have no cultural / historical / religious relevance and they are not related to manifestations of this type. The values are between 0.00 and 0.03 (Moldoveanu Peak), the values greater than 0 being given by the presence of iconographic representations as well as by the existence of myths / symbols related to the respective geomorphosite (Table 3).

Făgăraș Massif is next to Bucegi Massif one of the important natural tourist areas, which is why the economic component, respectively the management and use component, have high values in comparison with the other Carpathian Massifs.

For the economic value these vary between 0.8 (Revolverul Cliff) and 0.19 (Capra Cirque), while for management and use the values are between 0.11 (Stan Valley, Râiosu Cirque) and 0.18 (Arpășelului Ridge, Moldoveanu Peak, Vânătoarea lui Buteanu Peak) (Table 3).

In order to highlight the links between the analysed values and the total value, the linear regression method between variables was applied (Figures 4, 5, 6, 7, 8).

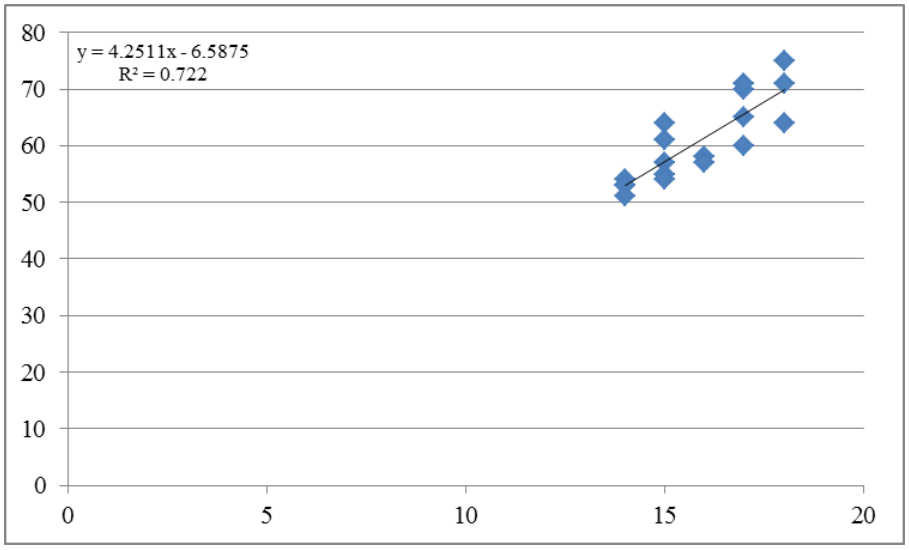

Figure 4. The correlation between scientific value and total value

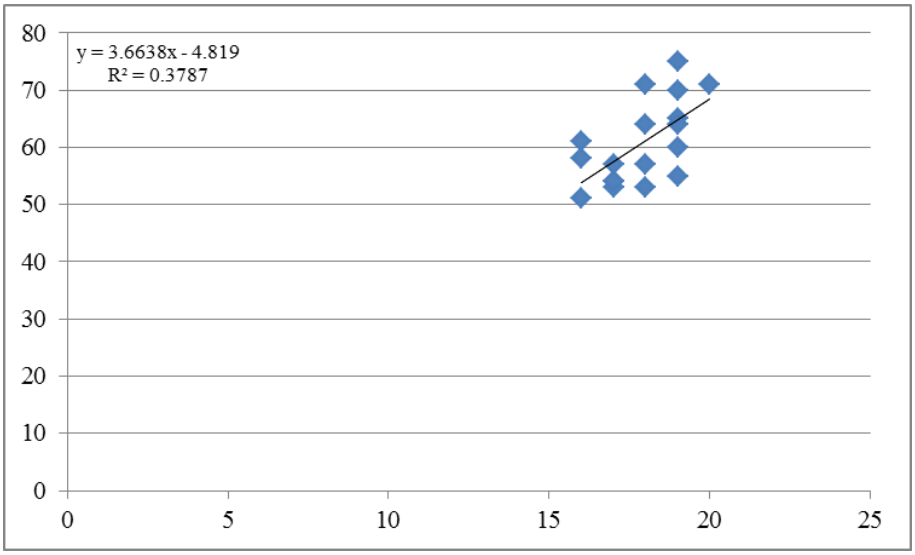

Figure 5. The correlation between aesthetic value and total value

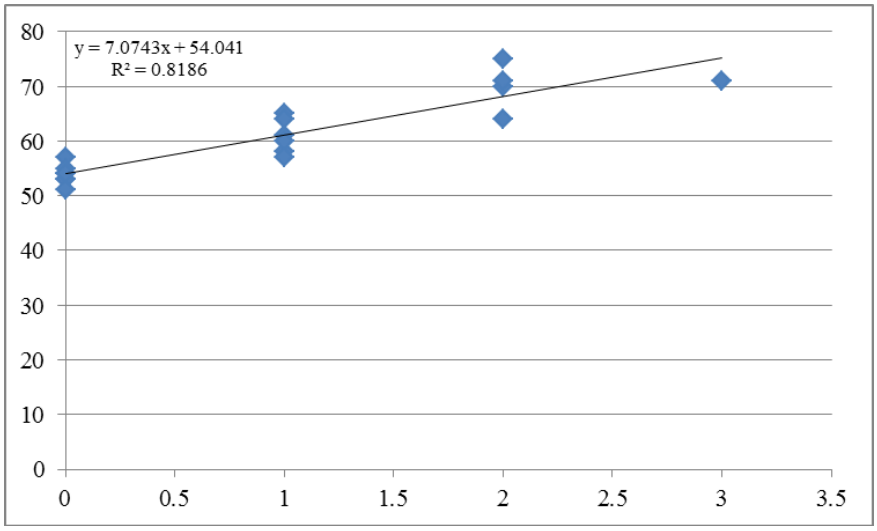

Figure 6. The correlation between cultural value and total value

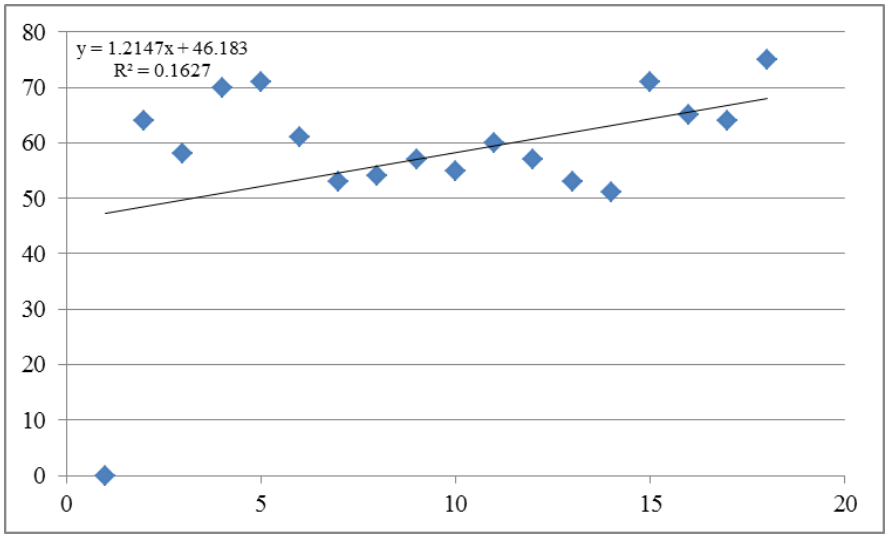

Figure 7. The correlation between economic value and total value

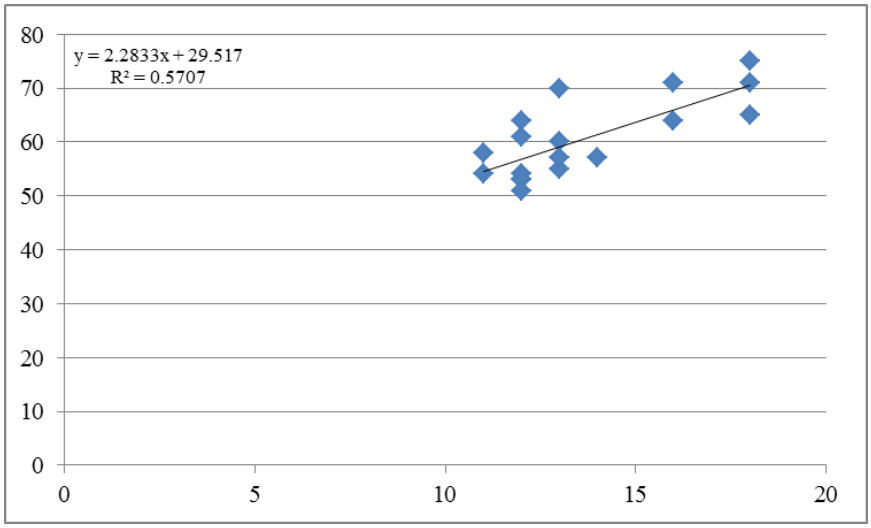

Figure 8. The correlation between management/ use and total value

Thus the highest correlation coefficient R = 0.90 is between the cultural value and the total value. The lowest coefficient R = 0.60 is between the aesthetic value (which as mentioned above is the most subjective) and the total value.
The values of the correlation coefficients between 0.60 and 0.90 demonstrate the high degree of interdependence between the values of the geomorphosites, as well as their associative tendency in most cases.

CONCLUSIONS

The proposed method was previously applied in Ponoare protected natural area (Mehedinți Plateau), the selected geomorphosites being exclusively karst. The obtained values were between 0.75 (Ponoare Natural Bridge) and 0.35 (Ponoare Sinkholes Field) [3]. The upper basin of Arges river is predominantly located in crystalline schist and isolated, limestones, the dominant landforms being glacial, periglacial and fluvial. The score obtained by the selected geomorphosites is higher than in the first case, being between 0.75 (Vânătoarea lui Buteanu Peak) and 0.51 (Izvorul Moldoveanu Valley). This is due both to their scientific value, Făgăraș massif being representative from the point of view of the glacial and periglacial relief as well as the easier accessibility compared to Mehedinți Plateau for many of them (Transfăgărașan National Road and Bâlea Waterfall - Bâlea Lake cable car).
The evaluation of geomorphosites has an important practical - applicative component, related to the realization through the geomorphosites map of the geotouristic one, which allows the use of the most valuable of them in tourism or as a model in the didactic activity. The second direction of use is given by establishing measures for the conservation of geomorphosites, respectively their introduction in projects related to the environment and territorial planning.

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