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MORPHOGRAPHIC STUDY OF BOIULUI VALLEY HYDROGRAPHIC BASIN

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Abstract: The aim of the present paper is to determine the morphometric parameters and features of Boiului Valley hydrographic basin. The basin is located in a karst area, in Pădurea Craiului Mountains, Romania, which makes it special, as the rivers flow through soluble rocks. We selected a small basin in order to analyse its morphometric elements and check if the morphometric laws of hydrographic basins are respected in the same way by the rivers flowing in karst areas. We applied the classical working method, that is processing the information from the topographic maps and with the help of the ArcGis soft we managed to measure the major morphometric indicators: the surface of the basin, the area, the shape factor, the length and width of the basin, drainage basin asymmetry factor and sinuosity index.

Key words: Boiului Valley, Pădurea Craiului Mountains, morphometric parameters, river segments, karst relief

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INTRODUCTION

The karst relief from Pădurea Craiului Mountains has been studied intensively over the years (Bordea, 1978; Rusu, 1988; Cocean, 2000; Racoviță et al., 2002; Ford et al., 2007) both for research purposes and also for its attractiveness offered by endokarst and exokarst forms as well. The karst landscape provides a wide range of forms of relief which contribute to its unique beauty and represent the main reason for tourism: sinkholes, uvalas, karren, karst plateaus, dry valleys, blind valleys, gorges, defiles, potholes, caves or karst springs.

A hydrographic basin can be studied as an open system that evolves constantly due to its exchange of matter and energy with the surrounding environment and also under the influence of the rivers and streams that shape the earth's surface (Zăvoianu, 2006). The drainage system determines the form and surface of the hydrographic basin and thus, its characteristics. The variables that characterise a basin are under the influence of the geological features (lithology, structure), morphometric elements (elevation, slope, degree of fragmentation, depth of fragmentation), vegetation (type, density) and human influence (Zăvoianu, 1978; Pradhan et al.,

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2012; Blaga et al., 2014). According to these variables, a hydrographic basin can be very small, peripheral, like the first-order ones, and huge that spread on thousands of square kilometers with one main collector and countless tributaries. The bigger the basin, the more complex the hydrographic network (Loghin, 2009). We have chosen a smaller hydrographic basin which covers mainly a karst area to assess if the morphometric rules applied to hydrographic basins in general are relevant for this network as well.

A lot of disparities may appear in a karst relief where the surface drainage is more complicated and the underground flowing is quite common because of the presence of karst springs and potholes. The configuration and dimension of the drainage system is responsible for the shape and surface of the hydrographic basin. Any hydrographic basin is unique being shaped by geologic features, morphometric variables, soil, vegetation and human intervention. All these factors are interconnected and act simultaneously (Zăvoianu, 2006).

STUDY AREA

Boiului Valley is situated in the north-eastern part of Pădurea Craiului Mountains between Brătcuţei Valley and Iadei Valley. It flows into Crişul Repede river, in the proximity of Lorău village (Figure 1).

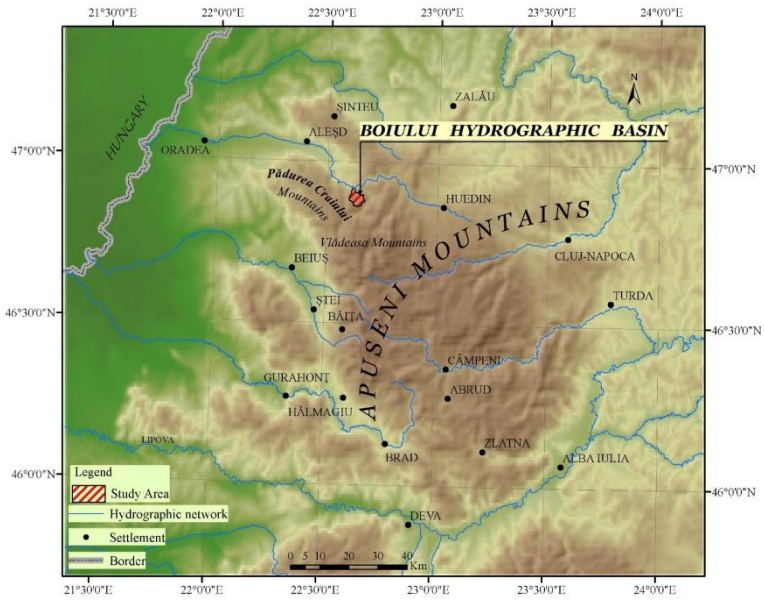

Figure 1. Location of Boiului Valley in Pădurea Craiului Mountains

It is important to take into consideration the fact that 83% of Pădurea Craiului Mountains consists mainly of mezozoic sedimentary formations belonging to three sedimentary cycles Triasic, Jurasic and Cretacic (Rusu, 1988). The sedimentary rocks formed during these stages are karst rocks which led to the appearance of a very rich and varied karst relief. The river runs through different types of rocks (limestone, dolomite, conglomerate, sandstone) creating sections of large valley with small slope or deep, narrow sections with waterfalls (Figure 2). It has many temporarily active tributaries or permanent ones. Due to the presence of positive and negative forms of relief and their horizontal and vertical layout, the relief is highly fragmented. Thus, the surface hydrographic network can be disorganized with portions of streams disappearing in the underground network. Boiului Valley is a karst valley with no gorges, that displays a seven-meter high waterfall, Boiului Waterfall, that represents the main tourist attraction of the area.

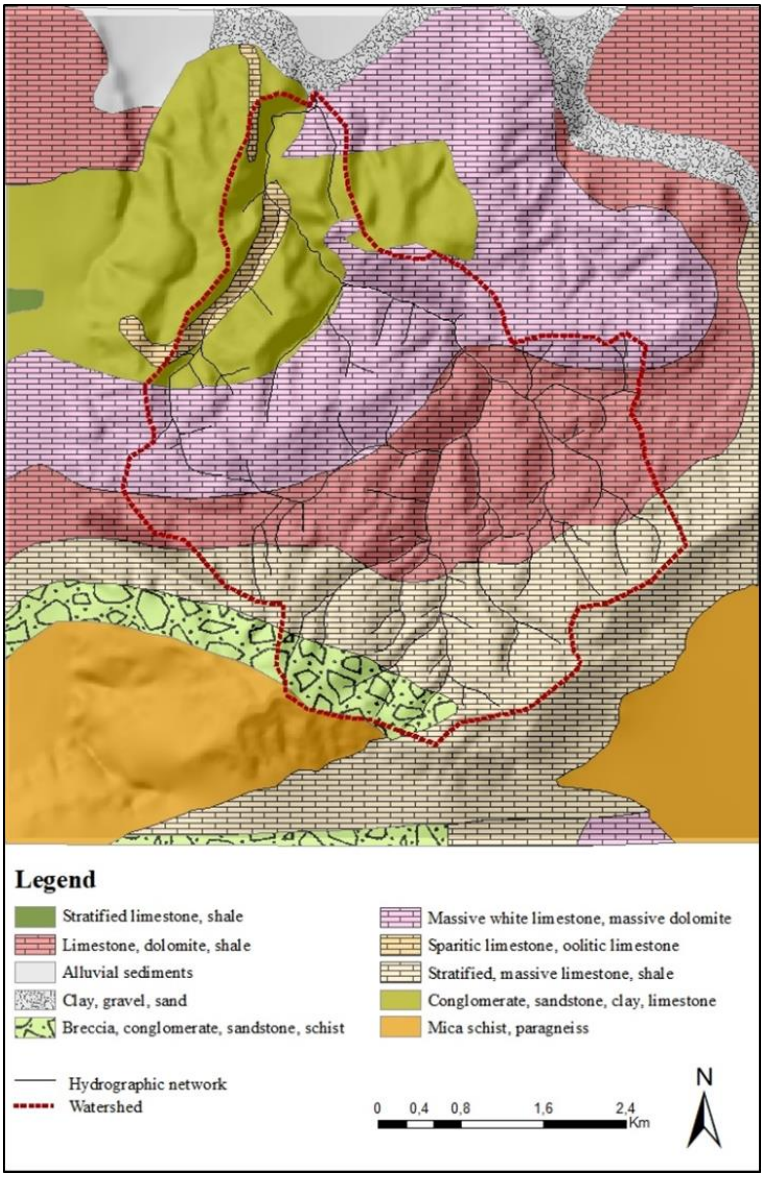

Figure 2. The geologic map of Boiului Valley basin in Pădurea Craiului Mountains
(Data source: Geologic map 1:200.000, Romanian Geologic Institute, 1978)

MATERIALS AND METHODS

For carrying out the present study, we started from the research expert studies published in the field of fluvial geomorphology and the morphometry of the river basins, among which we mention Strahler's Geografia fizică published in 1973, Morfometria bazinelor hidrografice, published by Ion Zăvoianu in 1978, Morfologia şi dinamica albiilor de râu written by Ichim and Rădoane in 1989, Relieful şi amenajarea teritoriului, by Lucian Blaga, Nicolae Josan and Dorina Camelia Ilieş, published in Oradea, in 2014.

The cartographic support was represented by the topographic map, scale 1:25.000 DTM from 1984 and the geologic map, scale 1:200.000 IGR from 1978 whose content was processed

using the instruments offered by the Arc Gis soft. We analysed the morphometric features of the basin, hypsometry, slope, slope exposure, depth of fragmentation, fragmentation density and some morphometric parameters of the basin and hydrographic network as they hold a crucial role in the formation and distribution of the elements of the river: the surface of the basin, its area, the shape factor, length and width of the basin, drainage basin asymmetry factor and sinuosity index. We used the procedure on hydrographic basins because we consider that it reflects objectively the reality of the area. The morphometric parameters were calculated according to the mathematical equations presented by Strahler (1973) and later by Zăvoianu (1978). Based on these concepts, we have calculated the number of river segments, the morphometric parameters and morphometric features of Boiului Valley hydrographic basin.

RESULTS AND DUSCUSSIONS

The number and order of the river segments

Determining and analysing the morphometric elements of a river basin represent a key factor that influences all the aspects concerning life within that particular territory. It is important to determine the river segments with permanent and temporary flow in order to calculate the main morphometric elements. The present study focuses on the determination of river segments in Boiului Valley hydrographic basin from Pădurea Craiului Mountains, in order to establish the main morphometric parameters of the basin.

The length of the river segments from the spring to the mouth is 8,5 km. The hydrographic basin of Boiului Valley has a dendritic drainage system in which most of the tributaries flow into the river in an angle smaller than 90°.When we analysed the hyerarchy of the hydrographic network in Boiului Valley, we took into consideration all the thalwegs, permanent and temporary ones.

According to the delimitation of the river segments in ArcGis, we noticed that the hydrographic basin has 64 first-order steams, which are most often temporarily active or disappear underground due to the limestone substrate they flow on. There are 20 second-order streams and 4 third-order streams (Figure 3). The overall number of the river segments is 89.

In the hydrographic basin of Boiului Valley there are 15 second-order sub-basins with a total surface of 11,41 km² and 4 third-order sub-basins that cover an area of 12,543 km². What is left of the total area of the hydrographic system (19,196 km²), that is 7.7 km², falls within the category of the interbasinal areas belonging to the fourth-order stream (Figure 3).

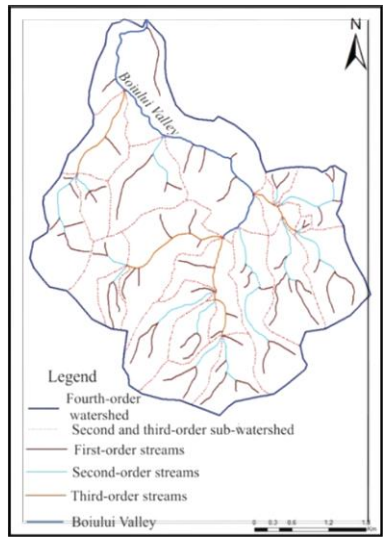

Figure 3. River segments and sub-watersheds in Boiului Valley

It is noticeable that in the studied area there are over three times more first-order segments than second-order ones; five times more second-order river segments than third-order ones and four times more third-order segments than the fourth-order which is the order of the main river. The differences among the ratio of bifurcation could be represented by the differences in the form of the river networks and by the fact that they flow in a karst area. The average of the three ratio coefficients is slightly over 4, which is a good value for the progression (Table 1). Knowing the number of river segments and their corresponding orders, we could establish the ratio of bifucation applying the mathematical formula $Rb = N_u/(N_{u+1})$.

Table 1. Number of river segments, orders and the ratio of bifurcation in Boiului Valley basin

Order (u)	Number of segments (N_u)	Ratio of bifurcation (Rb)
I	64	
II	20	3,20
III	4	5,00
IV	1	4,00

Table 2. The average length of river segments

Order (u)	Number of segments (N_u)	Average length (m)
I	64	402,319203
II	20	700,694053
III	4	1611,613525
IV	1	5357,160156

Analysing the number and the length of the river segments (Table 2) we can say that their number decreases as the order gets higher and their average length increases with the order. This observation is based on the law of the river segments, the law of the total length and the law of the average length.

Applying to Boiului Valley the Horton Law of the river segments, we can state that for an average 4 bifurcation coefficient and the main river segment being of order 4 as well, then the number of segments will be 1, 4, 16 and 64. The geometric progression of the numbers has a steady growing ratio, which means that each number bigger than 1 is the quadruple of the previous number (Table 3).

Table 3. The river segments measured and calculated according to the Horton Law

Order	Measured	Calculated
I	64	64
II	20	16
III	4	4
IV	1	1

The morphometric parameters of Boiului Valley

The surface of the basin is 19,196 km², which places it in the category of small hydrographic basins. It is an open basin, with an elongated shape from north to south and with a significant layout of the tributaries on the left side of the main river.

The area of the basin given by the watershed that delineates the surrounding basins (Brătcuţa in the west and Iada in the south-east) is 19,242 km, a value obtained using the ArcGis instruments.

The shape factor is the ratio between the surface of the basin and its square length 19,196 / 41,47797 = 2,160761 km. The length of the basin is the distance between the most remote points

on the river course and has a value of 6,44034 km. The maximum width is calculated as the maximum perpendicular on the line of its length and has a value of 5,13971 km. The average width is calculated as a ratio between the surface and the length, that is 19,196 / 6,44034 = 2,98058 km. The average width calculated on the two slopes equals 1,26574 km for the right one and 1,72236 km for the left one.

The drainage basin asymmetry factor involves the knowledge of both slopes, right and left. The distribution of the surface of the basin on the two slopes indicates a proportion of 57,78% for the left one and only 42,22% for the right one. According to this distribution, Boiului Valley hydrpgraphic basin is asymmetrical, developed more on the left side which covers 57,78% of the total area of the basin (Table 4). According to the formula $Kas = \frac{2(Supraf.Bst - Supraf.Bdr)}{Sb}$ the drainage basin asymmetry factor in Boiului Valley equals 0,30 and is due to the fact that most of the tributaries are located on the left side.

Table 4. The surface of the two slopes measured in km²

Boiului Valley	*Right slope*	*Left slope*
Surface	**8,15185 km²**	**11,0926 km²**

The sinuosity index is calculated as the ratio between the real length of the watershed and the length of the basin. For the left slope, this equals 9,071 / 6,440 = 1,408 km, and for the right one the value is 1,688 km, calculated as 10,871 / 6,440.

The morphometric features of the Boiului Valley hydrographic basin

We calculated the following morphometric features of Boiului Valley basin: hypsometry, slope, slope exposure, depth of fragmentation and the density of fragmentation.

Hypsometry

The average elevation of the basin is 650 m, the maximum elevation reaching 960 m in the south, of the basin, close to the springs and the minimum altitude is 327 m in the north of the hydrographic basin (Figure 4). This range of elevation places the basin among the mountainous hydrographic basins. Most of the basin, 9,65 km², is located at an altitude ranging between 650 m and 750 m (Figure 5). According to the data processed using interpolation in ArcGis, the average altitude of the land in 678,62 m.

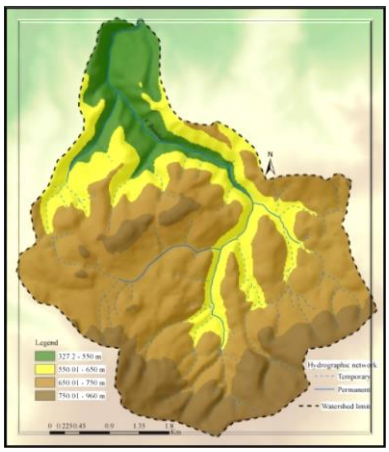

Figure 4. The elevation map of Boiului Valley hydrographic basin
(Source for elevation data: the contour lines taken from the topographic map 1:25.000, DTM, 1984)

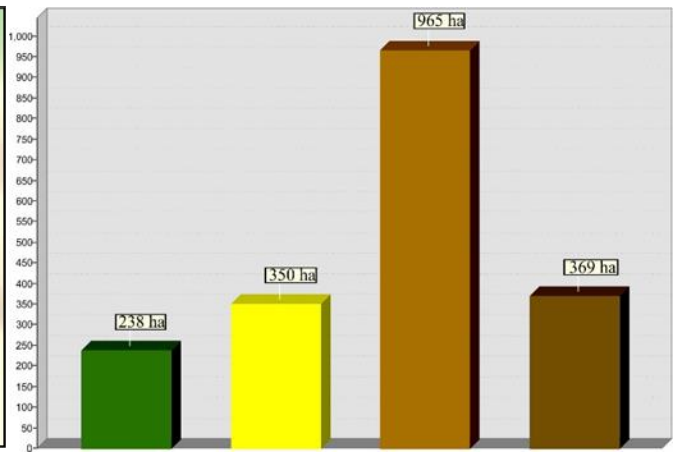

Figure 5. The histogram of elevation in Boiului Valley basin

Slope

The slope represents an important parameter for the use of land in the basin. We divided the area of the basin according to five categories of angles of declivity, as seen in table 5.

In the slope map (Figure 6) and the table below (Table 5) showing the tilt of the land, it is noticeable that the highest proportion of Boiului Valley basin covers a surface with an average tilt, between 6° şi 17°. The steepest areas are located along the main river and a few of its tributaries in the south of the basin.

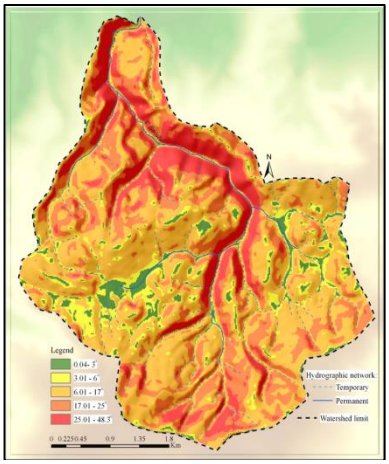

Figure 6. The slope map in Boiului Valley basin

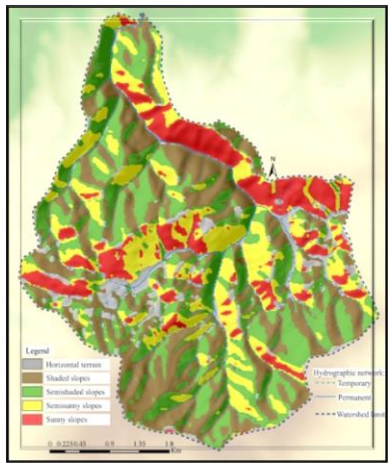

Figure 7. The slope exposure in Boiului Valley basin

Table 5. The characterization of the land from Boiului Valley basin according to the slope

Number	Slope	Characteristic of the land
1.	0° - 3°	horizontal land
2.	3° - 6°	slightly tilted
3.	6° - 17°	with average tilt
4.	17° - 25°	strongly tilted
5.	25° - 48°	steep

Slope exposure

According to Blaga et al. (2014), besides the horizontal land, there are four standard major groups for the slope exposure: the sunny slopes in the south and south-west, the partially sunny slopes in west and south-east, the semishaded slopes in east and north-west and the shaded ones in north and north-east. This ranking is clearly visible and easily identifiable on the slope exposure map (Figure 7). The horizontal land represented by the karst region is crossed mainly by a temporary hydrographic network.

Depth of fragmentation or vertical fragmentation

The depth of fragmentation shows the degree of depth of the valley and it is closely linked to the land fragmentation. We established five intervals for the depth of fragmentation, ranging from 2 m to approximately 92 m (Figure 8). The prevailing values are between 10 m and 25 m, and 25m and 50 m, respectively.

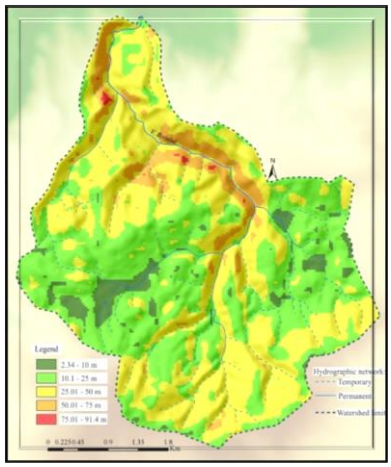

Figure 8. The depth of fragmentation in Boiului Valley hydrographic basin

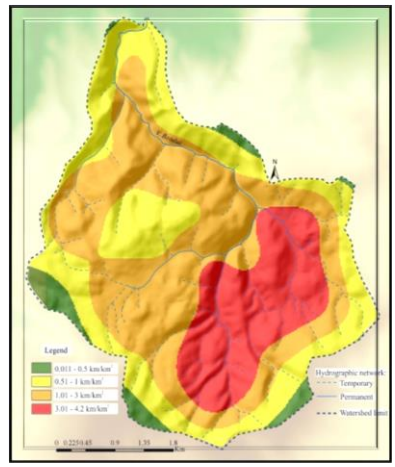

Figure 9. The fragmentation density in Boiului Valley hydrographic basin

Fragmentation density or horizontal fragmentation

The fragmentation density represents the degree of horizontal segmentation of the relief.

The fragmentation density is calculated as the ratio between the length of the drainage system and the surface of the basin, which in the present study represents 49,5987 km / 19,196 km² = 2,583 km/km². It can also be calculated taking into consideration the orders of the river segments (Figure 9). Therefore, the sum of the length of the first and second-order river segments divided by the surface of the second-order sub-basins, meaning 39,761 km / 11,418 km² = 3,482 km/km². The density of the third-order river segments in the basins with the same order equals 46,207 km / 12,543 km² = 3,683 km/km² (Table 6).

Table 6. The fragmenation density on orders of magnitude in Boiului Valley basin

Fragmentation density	**Order 2 network**	**Order 3 network**	**order 4 network**
	3,482 km/km²	3,683 km/km²	2,583 km/km²

CONCLUSIONS

For most part, Boiului Valley runs through a karst relief, thus some of the tributaries have an underground flow and the temporary surface network is active mainly during the rainy season. The land has a moderate tilt which makes it susceptible to erosion and land slides of low intensity. The morphometric laws applied to Boiului Valley demonstrate its capacity of self-organization and development even if it spreads over karst morphostructures, which usually disorganize the surface hydrographic network. The explanation lies in the fact that the studied area is quite small and located marginally within the landscape structure of Pădurea Craiului Mountains.

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