ZABALA HYDROGRAPHIC BASIN - THE MORPHOMETRIC ANALYSIS OF THE HYDROGRAPHIC NETWORK

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ABSTRACT. - Zabala Hydrographic Basin - The morphometric analysis of the hydrographic network. The South-East Carpathians are one of the most geodynamic regions of the Romanian territory. The rivers draining the South-East Carpathians have been studied under the aspect of the latest alterations of the main valley outline. An important database has been collected using the Horton-Strahler classification system, which has later been processed carefully concerning the rivers draining the South-East Carpathians, and a great deal of information has been extracted. What is more, the evolution of the hydrographic network has been related to the geological and tectonical states. Excellent results have been obtained by correlating the morphometric features of the hydrographic network with the geological and tectonical conditions of the studied area.

Keywords: the hydrographic basin, the main river course, river tributary, the river classification, and the morphometric model.

1. INTRODUCTION

The evolution of hydrographic basin is the outcome of the interaction between the matter flow (present mainly in the rain quantity received by the hydrographic basin area) and the energy condition (marked by the quantity of solar energy reaching the terrestrial surface). Tests carried out in previous years have shown that it is the precipitations that represents not only the main source of matter but the main factor in shaping the terrestrial surface. Current configuration of river network depends on many factors, such as: the altimetic position of the basin reported to the reference level; erosion resistance of constituent rocks; position of strata due to local tectonic evolution which has induced the current cofiguration of geological strata; random events, such as earthquakes, floods, deluges, vegetation covering degree; type of ground cover.

The specialized literature comprises a series of works quoting the above mentioned things: Mehedinţi (1931); Brătescu (1967); Vâlsan (1916); Mihăilescu(1968); Morariu and Velcea (1971); Rădoane (2003).

Measuring the forms of relief is acknowledged as a research method in Geography when transiting from the descriptive Geography to the explanatory-causative one, by Al. Humboldt (quoted by Zăvoianu, 1978). In addition, the

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morphometrical studies have proved extremely useful in explaining the relief evolution; they help us gain a faithful and correct image of the current aspect of the Earth and formulate paleo-evolutive or genetic predictions.

2.THE MATTER AND ENERGY FLOW IN THE ZABALA HYDROGRAPHIC BASIN

The matter and energy inputs of the system defined by the hydrographic basin area are dominated by the quantity of precipitations the soil receives. This quantity is supported by a certain quantity of energy consequently consumed in the processes occurring within the basin zone.The volume of the precipitations on the unit of surface depends on the latitudinal and altitudinal position of the respective basin, which influences the state of precipitation aggregation, as well. For example, the higher the altitude and latitude of the basin, the more its surface receives a higher quantity of solid precipitations. The average stratum of precipitations is approximately 615 mm in the area of the Sub-Carpathian of Curvature. Their repartition in time has played a great role not only in the processes occurring at the surface level but also in the amplitude of the replies and in dimensioning the morphology of the hydrographic basin.

The morphometric element which often varies due to the fluctuation of precipitations, over a long period of time, is the density of relief fragmentation; this indicator reflects the degree of relief evolution compared to the generations of valleys, thus the higher values have been recorded in the mountain area 3.5-4 km/sq.km, as well as in sub-mountain or inter-hills depression areas, due to hydrographic convergences.

The heavy rains that, most of the times, have disastrous effects due to the huge quantities of energy released, dislocate impressive volumes of sedimentary matters, or cause catastrophic floods (as it happened in 1969, 1970, 1972, 1975, 1979, 1991, 1992, 2004 and 2006, on most of the rivers in our country). The main phenomena caused by extreme values of precipitations are deluges and flood tides; they are due to the high degree of teeming, but also to the soil permeability, sloped river bottoms and mountains slopes, shape and area of the receiving basin. For instance, the 24-hour rainfall measured at Nereju hydrometric point, on 12th July 2005, reached 45 mm, only to reach 147 mm the following day same year.

2.1.Matter and energy output

The quantity of matter and energy as input within the limits of a hydrographic basin is distributed along the system morphodynamic processes, to alter its surface and configuration. Furthermore, it is stored differently, it acts on its compounds and induces a series of chain reactions, or simply drains off the basin through evapotranspiration, in the underground or as a result of human intervention.

The flowing is caused by the rain falling on the ground, process that determines the separation, spreading and transportation of soil aggregates; a part of the kinetic energy is absorbed by the vegetation, and the remained water quantities are alloted according to the condition of the basin surface, in connection with the fallen precipitations and the energy flow received from the Sun.

The water supplies of the mountainous and sub-Carpathian region of the Carpathian Curvature are provided by the surface waters (rivers) and, to a small extend, by the underground waters. Throughout a year, the debit distribution and river flows depend on the rainfall contribution in feeding the rivers, mainly pluvial (80%), the rest 20% being nival. A maximum is recorded in spring (April – May) with a peak in May – June, sometimes extending to July, followed by less water in fall-winter time due to the decrease of rains. The average volume of surface waters in the Putna basin has been estimated to 533 mil cubic metres, 182 mil cubic meters of which are discharged into the Putna through the Zabala and its affluent the Năruja.

The maximum debits have been the result of heavy rainfalls, generally downpours, and generated flood tides causing serious damages. The heavy falls on July 11th-13th 2005 in Putna hydrographic basin have been considered as the worst deluges and floods in history. For example, considering the average multi-annual flows in the River Zabala, the Rivulet Naruja recorded the historical maximum level of 257 cubic meters/sec, on July 25th 1977 at Herastrau station, the historical maximum level being of 150 cm (on the same date), and, in July 2004, the maximum flow was 294 cubic meters /sec and the maximum level of 270 mm; all these for an average multi-annual flow of 1.86; in the same place, it was recorded the maximum specific discharge of 3,526 l/sec/sq.km. At Nereju station, on the River Zabala, the historic maximum debit was 514 cubic meters /sec (July 25th 1977) and the historical maximum level of 198 cm, recorded on the same date; in July 2005, the maximum debit was 248 cubic meters /sec, and the maximum level 190 cm, all these for an average multi-annual debit of 3.84.

According to the gravitation law, water, at first, tends to seep in the soil or rock layer, but when the seepage capacity is exceeded, the drainage follows, the slope determines the evolution of the primary processes. A mountain side well protected by a carpet of vegetation will consume a great deal of the kinetic energy of the mass of moving water through friction; subsequently, its transport capacity will be dimished.

The specific conditions of the Romanian relief layering favour a strong bond between the water layer drained from the hydrographic basin and their average altitude (Ujvari, 1972).

Furthermore, the alteration of the surface of the hydrographic basins in this area and, the redistribution of matter and energy may be caused by the seismic movements detected lately, processes that might lead to the re-activation and emergence of landslides, visible mainly in the rural area within the Zabala hydrographic basin.

3. ORGANIZING THE HYDROGRAPHIC NETWORK

The Rivulet Zabala is one of the most important tributaries of the River Putna, with a 559 sq.km surface and a winding trajectory, the first half of the basin oriented towards NW-SE, and the second half oriented towards SE-NE. The Zabala junctions with the Putna at Grumaz (305 m altitude), not far from Prisaca. The Zabala springs from under Cabalasu Peak (1,619 m), its course is the result of the junction between the Zabaluta and the Arisoaia tributaries and has a surface of 546 sq.km, most of the tributaries are received on the right side and it crosses five villages: Nereju, Spulber, Paltin, Reghiu, Năruja. The basin has frequent course changes, because of the steep and unequal forming of main subCarpathian units; also, the river thalweg shows numerous tectonic and structural disturbances.

Some authors (Radulescu, 1973, Tufescu, 1966, Ujvari, 1972) consider that the Putna could have been the Zabala's affluent until the river capture left it 1 km shorter towards the Zabala, through the erosion of a spur-shaped sand stone rock, making it its affluent. These claims rely on the fact that at confluence, the Zabala's debit is stronger than the Putna's; here, the Putna meets the Vasui and, upstream Naruja village, it collects the most important affluent, the Naruja.

3.1.Models of Geomorphometric Analysis

In the second half of the 20th century, the system theory, with applications on sciences, submitted the morphohydrographic basin to a global analysis, an unisolated and open basin where the exchange of the matter and energy with the environment resulted in a morphogenetic balance. This exchange needs quantitative evaluations partially performed by using morphometric data. An extremely important role in the development of morphometric analysis, in establishing some laws and patterns of dimmensional evolution of the parameters of the hydrographic basins, was played by the system of ranking the hydrographic network drawn-up by Horton (1945) and completed by Strahler (1952), in which the elementary thalwegs are considered 1st order; these primary basins were considered of great value, „the cell in an organic tissue", by Baulig, in 1959.

The Horton–Strahler classification (ranking) system has been unanimously accepted because of its genetic foundation; it allows a comparative analysis of hydrographic basins, as well as quantitative evaluations of the stages of dynamic stability. This article has focused on the Order of river segments according to Horton-Strahler system and the geomorphometric model of drainage.

The Horton-Strahler ranking process differentiates between external sectors, up to the first junction (confluence) on the thalweg (of the first order) and internal segments, whose size varies according to the quality of the segments in connection. Each segment can link with segments of lower order without changing the size. The qualitative change is done when two segments of the same order join each other.

4.THE GEOMORPHOMETRIC MODEL OF DRAINAGE

This model requests the following: the number of river segments; the sum of the lengths of the river segments; the average of lengths of the river segments.

The number of river segments.

Each work stage needs the following activities: specifying the order of the river segments; counting the segments of each order and establishing the succession of the river segments for each basin. The study of these elements has formulated of the following law:

Law. The number of increasing successive river segments tends to decrease in geometrical progression, in which the first term N_1 is the number of segments of the first order. The ratio is the report of confluence R_C:

$R_C = \frac{N_x}{N_{x+1}}$. A report of confluence may be established for each pair of segments:

$$R_{C_1} = \frac{N_1}{N_2} \ldots R_{C_2} = \frac{N_2}{N_3} \quad \text{or} \quad R_{C_1} = \frac{\sum_{i=1}^{n} R_{C_i}}{n}$$

The reports of partial confluence (R_{C1}, ... , R_{Cn}) allow comparisons of confluences from several hydrographic basins and on different sectors of the basins (superior, middle, inferior). The data are graphically represented in semi-logarithmic coordinates.

The sum of the lengths of the river segments.

Each work stage studies the following activities: measuring the length for each order and the sum of lengths for each order.

Law. The sum of the lengths of the river segments of successive orders tends decrease in geometrical progression, in which the first term is defined by the sum of the length of the segments of the first order L_1. The ratio R_L is given by the sum of the length report: $R_L = \frac{L_x}{L_{x+1}}$

The average lengths.

It is worth mentioning the work stages: the calculation of the average length of each river segment for each order by reporting the total length to the number of river segments:

$$l_1 = \frac{\sum L_1}{N_1}; l_2 = \frac{\sum L_2}{N_2}$$

Law. The average length of the river segments of successive increasing order increases in geometrical progression, in which the first term is given by the average length of the courses of the first order l_1. The ratio r_l is given by the fraction of successive average lengths or by the fraction between the ratio of the river segments series and the average lengths: $r_l = \frac{R_C}{R_L}$

5. GRAPHS

In semi-logarithmic coordinates, x axis shows the size orders, as dependent variables: the number N of river segments, L length, the average length of river segments 1. The line defining each parameter will be drawn so that it contains as many points possible (values). The values diverting from the line show the morphogenetics conditions of the relief and the stage of its evolution.

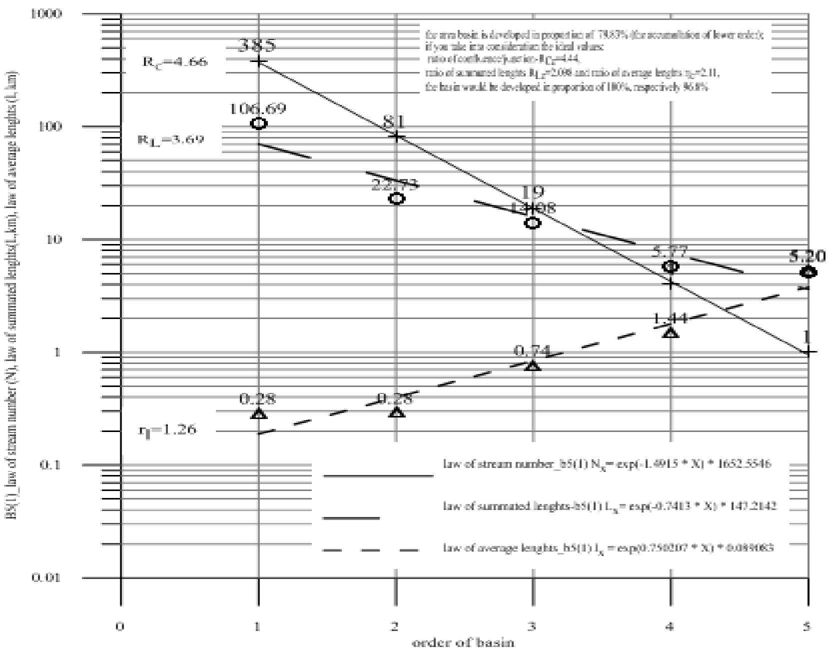

Fig.1. ***The geomorphometric model of drainage of the Zăbăluţa River.***

The graph illustrates the geomorphometric model of drainage of the Zăbăluţa River; the size order of the river (4.96) is made at the point of intersection determined by the following values: N_s=1.012313, L_s=3.724902 and l_s=3.6773. Also, it follows the main rule $1<R_L<R_C$, namely 1<3.69<4.66 or $1<r_l<R_C$, namely 1<1.26<4.66 (Table1).

Table1. ***The dates for the geomorphometric model of drainage of the Zăbăluţa River***

	Parameter		Order					Progress ratio
			1	2	3	4	5	
The Zăbăluţa River	Number of river segments (N)	Measured	385	81	19	4	1	R_C=4.66
		Calculated	385	82.54	17.69	3.79	0.814	
	Sum of lengths L(km)	Measured	106.69	22.73	14.084	5.77	5.2	R_L=3.69
		Calculated	106.69	28.89	7.83	2.12	0.574	
	Average length l(km)	Measured	0.277	0.2806	0.743	1.443	5.2	r_l=1.26
		Calculated	0.277	0.3501	0.442	0.559	0.706	

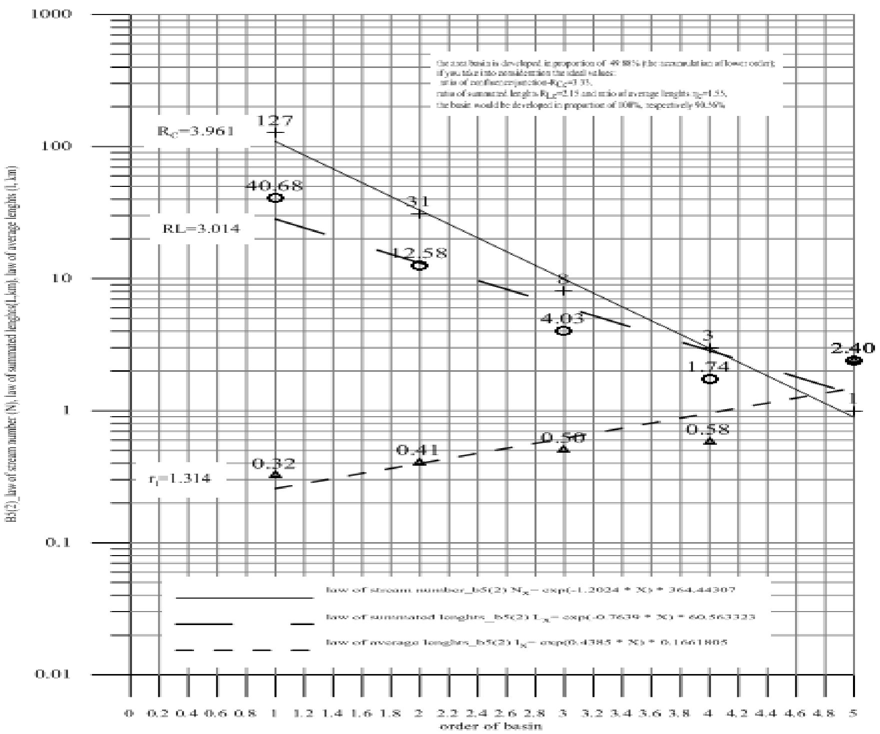

Fig.2. ***The geomorphometric model of drainage of the Goru River.***

The graph illustrates the geomorphometric model of drainage of the Goru River; the size order of the river (4.9) is made at the point of intersection determined by the following values: N_s=1.006632, L_s=1.43416 and l_s=1.4247. Also, is respected the main rule $1<R_L<R_C$, namely 1<3.014<3.961 or $1<r_l<R_C$, namely 1<1.314<3.961.

Table2. ***The dates for the geomorphometric model of drainage of the Goru River***

	Parameter		Order					Progress ratio
			1	2	3	4	5	
The Goru River	Number of river segments (N)	Measured	127	31	8	3	1	R_C=3.961
		Calculat	127	32.062	8.09	2.04	0.516	
	Sum of lengths L(km)	Measured	40.684	12.58	4.028	1.74	2.4	R_L=3.014
		Calculated	40.684	13.496	4.477	1.485	0.493	
	Average length l(km)	Measured	0.3203	0.406	0.504	0.5796	2.4	r_l=1.314
		Calculated	0.3203	0.42095	0.5531	0.7268	0.9551	

6. CONCLUSIONS

The lenghts of the network of the hydrographic basins are determined, in the first place, by the progressions which establish the morphometric pattern of the drainage. The report between the sum of the lenghts and the size order of the flows specific to each order, equals the total length of the river segments in a given basin.

The main morphometric parameters of principal and secundar valleys are very important in establishing the methods of fighting against surface and in-depth erosion, developing the torrential basins, the methods of preventing floods and charting risk maps (the form of basins, the sinuosity coefficient and the length of the valleys are taken into consideration in order to calculate the flood tide propagation time).

REFERENCES

1. Brătescu, C. (1967), *Works.* Scientific Publishing House, Bucharest.
2. Baulig, H. (1959), Morphométrie. Ann.Géogr., nr.369, LVIII, sept.-oct.
3. Horton, R.E. (1945), *Erosional development of stream and their drainage basins: hydrophysical, approach to quantitative morphology*. Geol.Soc.Amer., Bull.56.
4. Mehedinţi, S. (1931), *Terra.* Bucharest.
5. Mihăilescu, V. (1968), *Theoretical Geography.* Academy Publishing House R.S.R., Bucharest.
6. Morariu, T., Velcea, Valeria (1971) , Principles and Methods of Reasearch in Physics Geography. Academy Publishing House R.S.R., Bucharest.
7. Rădoane, N. (2003), Geomorphology of Small Hydrographic Basins. Ed. Uni.Suceava
8. Strahler, A. (1952,a), Dynamic basin of geomorphology. Geol.Soc.Amer., Bull.63.
9. Tufescu, V. (1966), Natural Shaping of Relief and Accelerated Erosion. Scientific Publishing House, Bucharest.
10. Ujvári, I. (1972), *Water Geography of Romania*. Scientific Publishing House, Bucharest.
11. Vâlsan, G. (1916), *The Romanian Plain*. B.S.G.R.
12. Zăvoianu, I. (1978), *Morphometry of Hydrographical Basins,* Academy Publishing House, Bucharest.