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THE HORTON-STRAHLER RIVER ORDER IMPLEMENTATION RELEVANCE WITHIN THE ANALYSIS OF THE ALMAŞ BASIN RELIEF

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ABSTRACT. - The Horton-Strahler River Order Implementation Relevance within the Analysis of the Almaş Basin. The purpose of the present study/research aims at underlining the importance of the enforcement of the river order within the analysis of the Almaş basin relief. The topic was chosen based on the fact that the hydrographic networks hierarchy offers at the same time quality and quantity information, on the relief evolution tendency and also the chance to compare the Almaş tributary sub-basins ones with the others and also with other basins of the same order belonging to other morphological units. The results thus achieved offer information on the rivers order, the confluence report, the river segments density, the form/shape report. The values corresponding to the previously mentioned index, have led us to formulating the following conclusion: the evolution of the Almaş hydrographic network appears therefore strongly influenced by the lithologic sub-layer, by the presence of brittle rocks, by accentuated fragmentation and by the wide energy of the relief, nevertheless by the presence of the local subsidence area/region of Someș, from Jibou.

Keywords: *the Horton-Strahler Order, rivers, Almaş, depression, Transylvania*

1. INTRODUCTION

The present study focuses on the importance of the river order enforcement within the analysis of the Almaș river basin. Therefore, the reason for dwelling on the subject was the fact that the hydrographic network hierarchy offers both quality and quantity information, thus drawing the line of the evolution tendency in the area and also the possibility to compare the sub-basins ones with the others and also with other basins of the same order, belonging to different territories.

The hydrographic basin Almaș is part of the Almaș-Agrij Depression, a sub-unit of the peri-Carpathian Transylvanian area, at the junction between the Someșan Plateau and Meseș Peak. The Almaș Basin is generally characterized by wide, terraced valleys, narrow, low interfluves peaks, in report with the neighboring units.

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2. MATERIALS AND METHODS

In time, there have been a lot of proposals regarding the rivers order system. We find the first attempt, which considered as basis the river flow position as compared to the main collector, by Gravelius (1914), quoted by Horton(1945), who considers that the largest river is of the first order from its spring to its mouth. The tributaries which flow into it are of the second order, while those flowing into a second order water flow, are of the 3rd order and so on. In 1945 Horton reverses this classification system, by attributing the first order to the elementary thalweg. The second order water flow shall be the one receiving at least one or more first order tributaries (Zăvoianu, 1978). This classification system was implemented and developed in Romania by I. Zăvoianu (1978), Roșian (2008).

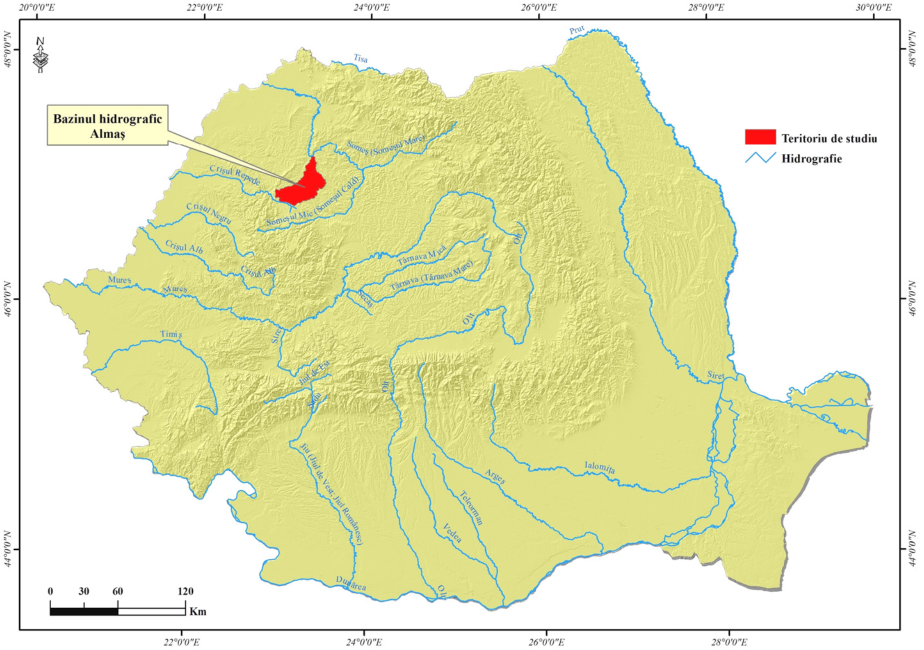

Figure 1. Geographical position of the Almaş Hydrographic Basin

In the present research paper, in order to achieve a hierarchy of the hydrographic network of the sub-basins corresponding to the hydrographic basin Almaș, I have applied the Horton-Strahler classification system. G. Roșian (2009) in his research paperwork "*Verifying the slopes order law in the Transylvanian Depression*" uses the slope order law, this being a derivate of the river order law in the Horton-Strahler system. This, together with "*The hydrographic basins morphometry*" (Zăvoianu, 1978) were used as methodological basis of the present study.

The river order law in Horton-Strahler system allows comparative studies, statistic data processing on value categories, of the various basins, as well as quantity evaluations of the dynamic equilibrium phases (Grecu și Palmentola, 2003, quoted by Roșian, 2009, p. 84).

a. The Law of the rivers number

It plays an important role in the morphometric analyses, especially in establishing certain relations relative to the evolution of the hydrographic basin parameters, thus contributing to "deciphering" the morphology of the basin object of the study.

R. E. Horton (1945, p. 291) created the law according to which: *the number of the rivers of various orders within a given basin tends towards a reverse geometric progression, in which the first term is the unit, whereas the ratio is formed of the bifurcation report.*

$$\mathbf{R_b=N_u/\ N_u+1}$$

where R_b – the bifurcation report;
N_u – the number of segments of a certain order;
u – the segment order.

I. Zăvoianu (1978, p. 40, quoted by Roșian, 2009, p. 85) reforms Horton's river number law, by stating as follows: *the number of river segments of successive orders, within a given hydrographic basin, tends to form a reverse geometric progression, in which the first term(N_1) is given by the number of the river flows of the first order, whereas the ratio is the confluence report (Rc).*

$$\mathbf{R_c=N_x/N_x+1}$$

where: R_c – the confluence report;
N_x – the number of segments of order x;

In order to calculate the confluence report we shall calculate the arithmetic mean of the individual reports (Roșian, 2009, p. 85).

$$\mathbf{R_c=(R_{c1}+R_{c2}+....+R_{cn})/n}$$

where: n – the river order;

Depending on the number of the river segments and on the basin surface we can calculate *the river segments density* (Zăvoianu, 1978, quoted by Roșian, 2009, p. 86), by applying the formula:

$$\mathbf{Dr=N/F}$$

where: Dr – the river segments density
N – number of the river segments
F – surface

In order to determine *the form report* (zav, quoted by Roșian, 2008) we can use the formula:

$$\mathbf{R_f=A_u/\ L_b^2}$$

where: A_u – basin surface
L_b – river length

3. RESULTS AND DISCUSSIONS

The use of these relations has contributed to creating an inventory of the previously mentioned indicators, for each single sub-basin, subsequently for the whole basin of the river Almaș (Table 2), which shall contribute to the analysis of the study territory. In order to identify and trace the first order networks, I have used the topographic maps 1: 25 000, following the method:"*the water course itinerary imprinted by a continuous or interrupted line*" (Ichim et al., 1989, p. 49) by using the methods offered by the ArcMap 10.1 program. The information refering to the water flows within the hydrographic basin Almaș (the confluence position, the length, the average slope, the sinuosity coefficient, the basins surface and average altitude), see table 1, were required for the calculus of the river segments density, the form/shape report, etc.

Table 1

Morphometric features of the main rivers within the Almaș basin

Water flow/course		**Water flow/ course information**			**Information on the Hydrographic basin**	
	Confluence position	**Length km**	**Average slope ‰**	**Sinuosity coefficient**	**Surface km²**	**Average altitude**
Almaș	**s**	**65**	**6**	**1.56**	**814.5**	**420**
Peștera	d	6	44	1.19	10	608
Dorogna	d	9	11	1.10	24	469
Jebuc	d	9	19	1.41	40	425
Martin	s	5	36	1.21	14	
Băbiu	s	17	13	1.22	70	437
Tăudu	s	9	15	1.08	20	425
Guiaga	s	7	11	1.03	10	390
Valea Cetății	d	13	20	1.13	24	457
Meștereaga	s	6	18	1.02	8	431
Petrindu	d	9	25	1.04	36	429
Dincu	d	7	31	1.48	13.5	422
Benaia	s	7	7	1.13	15	385
Bozolnic	d	11	13	1.14	55	417
Arghiș	s	8	26	1.32	17	428
Mierța	s	6	14	1.08	11	
Sâncraiul Almașului	d	13	13	1.14	33	391
Dolu	d	9	19	1.16	19	364
Sântă Mărie	s	13	11	1.12	61	335
Valea Mare	s	7	13	1.01	21	332
Ugruțiu	d	10	13	1.13	25	318
Dragu	d	12	8	1.09	67	363
Voievodeni	d	9	13	1.41	21	397
Printre Văi	d	11	13	1.08	47	383
Strâmba	d	6	9	1.22	15	
Jirnău	s	5	7	1.08	20	
Trestia	d	6	33	1.09	13	326

Table 2

Order, number of the river segments, the confluence report for the Almaș basin

Water flow/course	The Horton-Strahler Order	Number of river segments					The confluence report					Number of river segments	Density of the river segments (Dr=N/F)	The form report (R_f)
		N_1	N_2	N_3	N_4	N_5	N_1/N_2	N_2/N_3	N_3/N_4	N_4/N_5	Media Rc			
Almaș	**5**	**820**	**219**	**52**	**12**	**1**	**3.75**	**4.21**	**4.33**	**12**	**6.07**	**1104**	**1.35**	**0.19**
Peștera	**4**	19	5	2	1		3.8	2.5	2		2.93	27	2.7	0.27
Dorogna	**3**	16	6	1			2.67	6			4.3	23	0.95	0.29
Jebuc	**3**	12	4	1			3	4			3.5	17	0.42	0.49
Martin	**3**	11	5	1			2.2	5			3.7	17	1.21	0.56
Băbiu	**4**	45	11	3	1		4.09	3.67	3		3.6	60	0.85	0.24
Tăudu	**3**	17	3	1			5.67	3			4.35	21	1.05	0.24
Guiaga	**2**	5	1				5					6	0.6	0.20
Valea Cetății	**3**	8	2	1			4	2			2	11	0.45	0.14
Meștereaga	**1**	1										1	0.125	0.22
Petrindu	**4**	21	9	3	1		2.33	3	3		2.77	34	0.94	0.44
Dincu	**3**	9	2	1			4.5	2			3.25	12	0.92	0.26
Benaia	**2**	7	1				7					8	0.53	0.30
Bozolnic	**4**	81	13	3	1		6.23	4.33	3		4.52	98	1.78	0.45
Arghiș	**3**	12	3	1			4	3			3.5	16	0.94	0.26
Mierța	**3**	10	3	1			3.33	3			3.15	14	1.27	0.31
Sâncraiul Almașului	**4**	66	16	3	1		4.12	5.33	3		4.13	86	2.60	0.19
Dolu	**3**	29	5	1			5.8	5			5.4	35	1.84	0.23
Sântă Mărie	**4**	63	20	5	1		3.15	4	5		4.05	89	1.45	0.36
Valea Mare	**4**	22	6	2	1		3.67	3	2		2.9	31	1.47	0.42
Ugruțiu	**3**	21	7	1			3	7			5	29	1.16	0.25
Dragu	**4**	63	14	3	1		4.5	4.67	3		4.05	81	1.20	0.47
Voievodeni	**4**	44	12	3	1		3.67	4	3		3.55	60	2.85	0.26
Printre Văi	**4**	72	16	3	1		4.5	5.33	3		4.27	92	1.95	0.39
Strâmba	**3**	34	4	1			8.5	4			5.5	39	2.6	0.42
Jirnău	**3**	24	6	1			4	6			5	31	1.55	0.8
Trestia	**4**	41	8	2	1		5.12	4	2		3.7	52	4	0.36

This type of analysis of the hydrographic basin has offered the chance to obtain the river order values, the number of the river segments and the previously mentioned parameters. They were useful in establishing the evolution stage, the river segments density, the form report, the fragmentation degree, the geomorphological processes rate, etc.

"The actual drainage structure given by the number of the river segments, is the result of a long evolution process, developed by objective laws, according to which the morphometric elements tend to achieve their equilibrium/an equilibrium point, as a result of the interaction between the sub-layer and the hydro-metrological factors."(Roșian, 2008)

Within the basin object of the study, the 5th size order was achieved (the Almaș river). It is followed by basins of the 4th order (Peștera, Băbiu, Petrindu, Bozolnic, Sâncraiul Almașului, Sântă Mărie, Valea Mare, Dragu, Voievodeni, Printre Văi, Trestia), of the 3rd order (Dorogna, Jebuc, Martin, Tăudu, Valea Cetății, Dincu, Arghiș, Mierța, Dolu, Ugruțiu, Strâmba, Jirnău), of the 2nd order (Benaia și Guiaga) and of the 1st order (Meștereaga). The number of the river segments of the Almaș basin is of 1104, the elementary thalwegs numbering 820, which represents 74.2 % of the total number of the basin segments, which underlines the accentuated torrential erosion in the upper basins of the rivers, the increased fragmentation ratio and the valleys accelerated tendency to reach the dynamic equilibrium state.

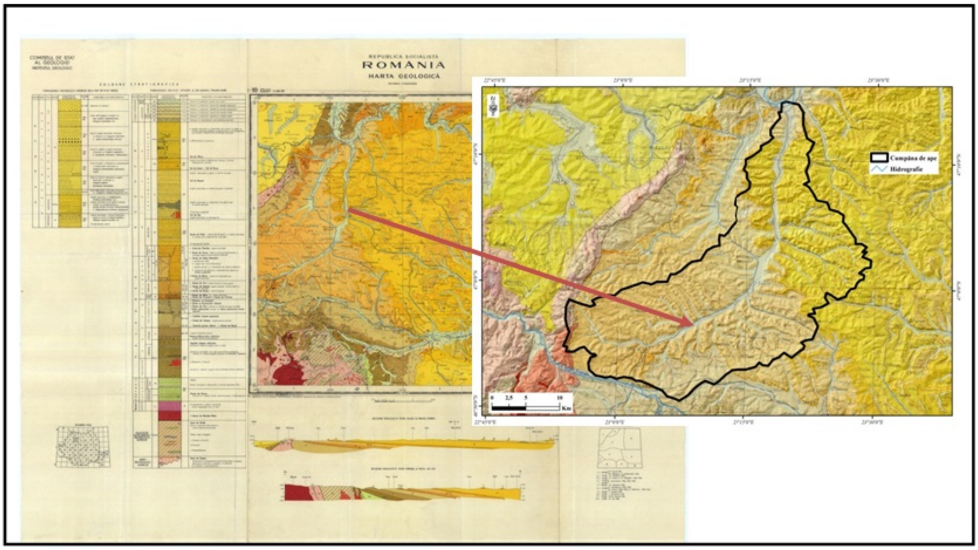

Figure 2. The Almaș Basin geological map

The analysis of the river order map within the Almaș basin and of the geological map confirms that the basin lithologic formations significantly influence the development of the hydrographic network, correlated with the slope.

The Eocene presence in the upper basin, especially the Priabonian, represented by lower coarse limestone, sandstones, upper stripped clays, marls, have determined a slight ramification of the upper flows for the right side tributaries: Jebuc, Valea Cetății and Petrindu. Consequently, the number of the 1st order segments and the river segments density registers reduced values, thus: Jebucu (12, respectively 0.42), Valea Cetății (8, respectively 0.45) and Petrindu (21, respectively 0.94).

Over the Eocene strata there are Oligocene strata in layers of Mera (lattorfian) formed of an alternation of marls and greenish-eggplant sandy clays, slightly stratified, with greenish sands, coarse calcareous sandstones and limestone. They look like a strip, reduced as dimensions/extension, ensuring the passage towards the second horizon characteristic to the Oligocene: the Rupelian (Ticu layers), with greater extension in the upper basin of the valley. Based on the Rupelian specific geologic formations (clays, sands, sandstones, marly limestone shale) the hydrographic network of Almaș displays a ramification superior as compared to the one of the Eocene. Representative for this areal shall be the basins Băbiu, a left side tributary, of a value of 45 for the order segments 1, and Bozolnic, a right-side tributary of the middle basin, which registered the value of 81 for the number of the river segments of the 1st order. The aquitanian-chattian formations (the Zimbor and Sânmihai layers) are widely spread within the Almaş basin. Updated they appear in the middle basin spread over a wide surface, then they are concealed, downstream of the place Hida, of the more recent formations, reappearing la zi only in the lower course, downstream the place Gâlgău. The Oligocene series terminates with the Sâmnihai layers, red clays with gravels which mark the passage to the Inferior Miocene (Burdigalian and Helvetian)-conglomerates, sand stones, clay marls, with an ample development on the right slope of the Almaș river, beginning downstream the place Hida up to Gălgău. It is on their account that the Almas hydrographic network strongly branched and deepened. What we should mention to this effect are the right side tributaries of Almaș: Dragu with its tributary Voievodeni, Printre Văi with its tributary Strâmba, Trestia. The order reached in the case of basines Dragu, Printre Văi and Trestia is the 4th order. For the rivers Jebuc, Valea Cetății and Petrindu, with their upper basins developed during the Eocene and characterized by average slopes of 19 %, 20%, respectively 25 %, the number of the 1st order segments is 12 (Jebuc), 8 (Valea Cetății), respectively 21 (Petrindu), which indicates the fact that the slope and the rock type influence the hydrographic network development.

4. CONCLUSIONS

As for the river bed networks, the slope is an element of outmost importance by its dynamic tightly connected to the sub-layer resistance to erosion, drainage basin access and exits. We shall therefore notice that the rocks which form the hydrographic basins sub-layer play an important role in dimensioning the morphometric elements. The hydrographic network hierarchy in Horton-Strahler system appears important in order to achieve the drainage model/pattern, the analysis of the water drainage on the slope, the soil risk exposure map, etc. The present study is precursory to the complex demarche of achieving the risk exposure map of the soils within the Almaș hydrographic basin.

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REFERENCES

1. Grecu, Florina, (1983), *Probleme ale formării și evoluției rețelei hidrografice din Depresiunea Transilvaniei,* Memoriile secţiilor ştiinţifice, Seria IV, tom. IV, București.
2. Grecu, Florina, (1992), *Bazinul Hârtibaciului. Elemente de morfohidrografie,* Editura Academiei Române, Bucureşti.
3. Ichim, I., Bătucă, D., Rădoane, Maria, Duma, Didi (1989), *Morfologia și dinamica albiilor de râuri,* Editura Tehnică, Bucureşti.
4. Ioniță, I.(2000), *Geomorfologie aplicată. Procese de degradare a regiunilor deluroase,* Editura Universității "Al.I. Cuza", Iași.
5. Irimuș, I.A. (2003), *Geografia fizică a României,* Ed. Casa Cărţii de Ştiinţă, Cluj-Napoca.
6. Irimuș, I.A., Vescan, I., Man, T. (2005), *Tehnici de cartografiere, monitoring și G.I.S.,* Edit. Casa Cărţii de Ştiinţă, Cluj-Napoca.
7. Mutihac, V. (1990), *Structura geologic a teritoriului României,* Edit. Tehnică, București.
8. Petcu, P. (1985), *Procese geomorfologice actuale din "Grădina Zmeilor",* Terra, anul XVII (XXXVII), nr. 2, București.
9. Petrea, D. (2005), *Obiect, metodă și cunoaștere geografică,* Editura Universității din Oradea, Oradea.
10. Roşian, Gh. (2008), *Modele de geomorfologie funcțională ale sistemului vale-versant din Depresiunea Transilvaniei,* Teza de doctorat, Universitatea "Babeş-Bolyai" Cluj-Napoca, Facultatea de Geografie.
11. Savu, Al. (1962), *Contribuții la studiul evoluției rețelei hidrografice din bazinul Almaș-Agrij,* Studia Univ. Babeș-Bolyai, Cluj-Napoca, Seria Geologie-Geografie, f.1.
12. Savu, Al. (1963), *Podișul Someșan. Studiu geomorfologic,* Teză de dizertație, Universitatea "Babeș-Bolyai" Cluj, Facultatea de St. Naturale-Geografie.
13. Zăvoianu,I., (1978), *Morfometria bazinelor hidrografice,* Edit. Academiei, București.
14. Zăvoianu, I., Florina, Grecu, Herişanu, Gh., Marin, Cornelia (2003), *Rolul rezistenței rocilor în dimensionarea unor elemente morfometrice ale rețelei hidrografice din Bazinul Slănicului Buzăului,* Analele Univ. "Spiru Haret" București, Seria Geografie, nr.6.
15. ***(1968), *Harta geologică a RS România, scara 1:200 000,* Foaia Cluj.
16. ***(1987), *Geografia României III. Carpații Românești și Depresiunea Transilvaniei* (sub redacția D. Oancea, Valeria Belcea, N. Caloianu, S. Dragomirescu, Gh. Dragu, Elena Mihai, Gh. Niculescu, V. Sencu, I. Velcea), Ed. Academiei Române, Bucureşti.