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Full Length Research Paper

Geomorphometric analysis on the some riverbeds in the Romanian plain

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The present study refers to some hydrographic basins in the Romanian Plain and appeals to morphometric methods based on the Horton Strahler river hierarchy system. The central part of the Romanian Plain located between Argeş (East), Olt (West), Cotmeana Piedmont (North) and Danube (South) has a highly dense hydrographic network. The Vedea and Neajlov basins (for which the major source of the trunk river is located in the alluvial deposits, rich in phreatic waters, were analyzed) and Calmatui, this explains the relatively high density of the drainage network in the upper part of these basins, proved by the high values of the confluence ratio for the low order streams (Rc1 = 5.56 – Cotmeana (river trybutari of Vedea); 5.15 – Neajlov; Vedea = 5.73). This is an unusual situation for a plain river but it is sustained by Schumm et al. (1995) demonstrations regarding the genesis of rivers of Stepheads type. The riverbed morphometry and morphography reflects the long-term dynamics and evolution, the employed models being complex and depending on the envisaged purpose. In the south-western of Plain Teleorman is the basin Calmatui, with high confluence ratio (Rc = 6.4). The geomorphometric analysis in the Horton-Strahler system accurately reflects differences among riverbeds as follows: a high value of the bifurcation ratio for the Vedea upper basin (at the contact plain-piedmont), oversized channel of the Neajlov, autochthonous Plain River (old riverbed of a Subcarpathian stream, high underground recharge rate from the Argeş alluvial fan). The values of morphometric parameters, obtained through direct measurements on maps emphasize riverbed dynamics. The cartographic document similar to present maps is the old cartographic document.

Key words: Riverbeds, geomorphometric analysis, drainage basin, Romanian Plain.

INTRODUCTION

The present study aims at analyzing the morphometric of drainage network based on the Horton-Strahler hierarchic system. According to this hierarchy structuring system, our drainage network analysis considers as 1st order streams those having no tributaries at all; the junction of two 1st order streams forms a 2nd order stream, etc. (Horton, 1945; Strahler, 1952).

This way of regarding stream order enables us to assess the links between stream density, channel length, drainage area/perimeter, etc. Moreover, it allows the comparison among different elements of drainage basin dynamics in terms of size and morphogenetic conditions.

In Romania, morphometric studies have been developed especially in drainage basins from mountain and hills units, after the researches of Zăvoianu (1978, 1985) and Grecu (1980, 1992, 2008). This study is applied to a plain unit.

The Romanian Plain is located in the central-southeastern part of Europe and in the south of Romania, stretching along the inferior course of the Danube, which borders it on the South and East. To the north, the Romanian Plain adjoins the Getic Plateau, the Curvature Subcarpathians and the Moldavian Plateau. It is the largest plain unit in Romania (52699 sq. km together with the Danube floodplain, which means approximately 1/5 of the Romania's total area) (Posea et al., 2005). The Romanian Plain territory corresponds to the drainage basin within the Carpathian-balcanic mountain arc, which imposed the hydrographic network and the lake's genesis.

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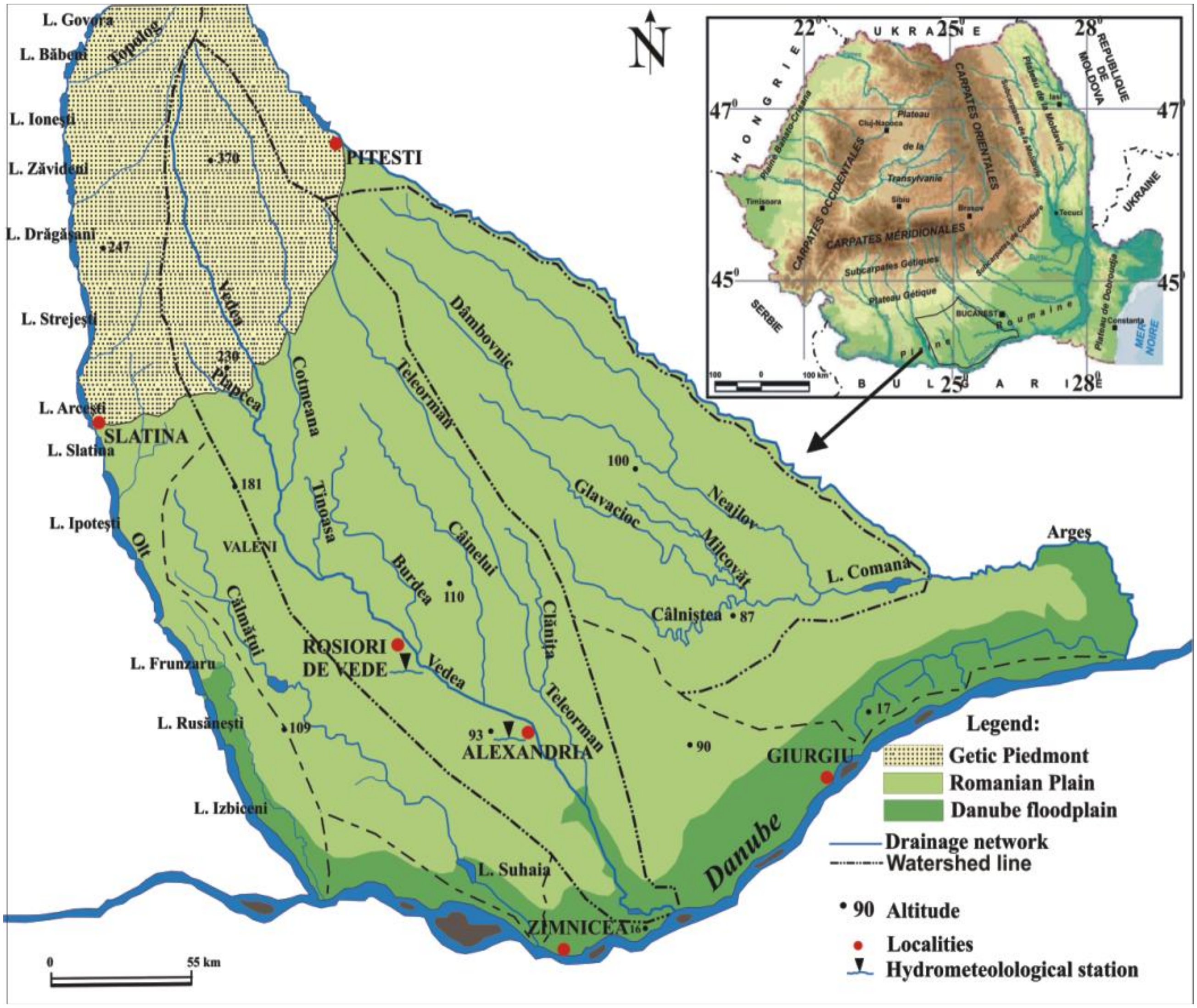

Figure 1. The location of the river basins within the Romanian Plain.

The relief includes various landforms, a result of the sub-aerial shaping of the alluvial-lacustrine infill deposits carried especially by the allochtonous and autochthonous streams. The shaping took place in several distinct phases (beginning with Upper Pleistocene and during Quaternary) and led to the formation of different genetic types of plains (due to deposits variety, neotectonics and hydrogeology): piedmont plains, glacis plains, terrace plains, subsidence plains, and alluvial-lacustrine plains (Cotet, 1976; Posea, 1997). On the interfluves, the terraces and floodplains, displaying morphometric and morphological specific features determined by the regional and local geological and hydrogeological conditions, stand out in the landscape. In this way, the contact with the northern physiographic units influences not only the dynamics of the Romanian Plain landforms, but also the riverbeds dynamics and morphology (Grecu, 2010).

The Danube River, whose course has formed in different periods of time, has contributed, together with the regression of the Pliocene-Pleistocene Lake towards east and northeast, to the genetic variety of the relief in the Romanian Plain. At the same time, it has imposed the general orientation of the hydrographic network.

Geographic position of the studied hydrographic basins

The present study refers to the streams located in the central part of The Romanian Plain, a territory delimited by the rivers Olt (to the west) and Argeş (to the east) (Figures 1 and 2). The Vedea River springs from the Cotmeana Piedmont at approximately 550 m altitude and flows into the Danube at approximately 20 m altitude. The total length of the main river collector is about 251 km

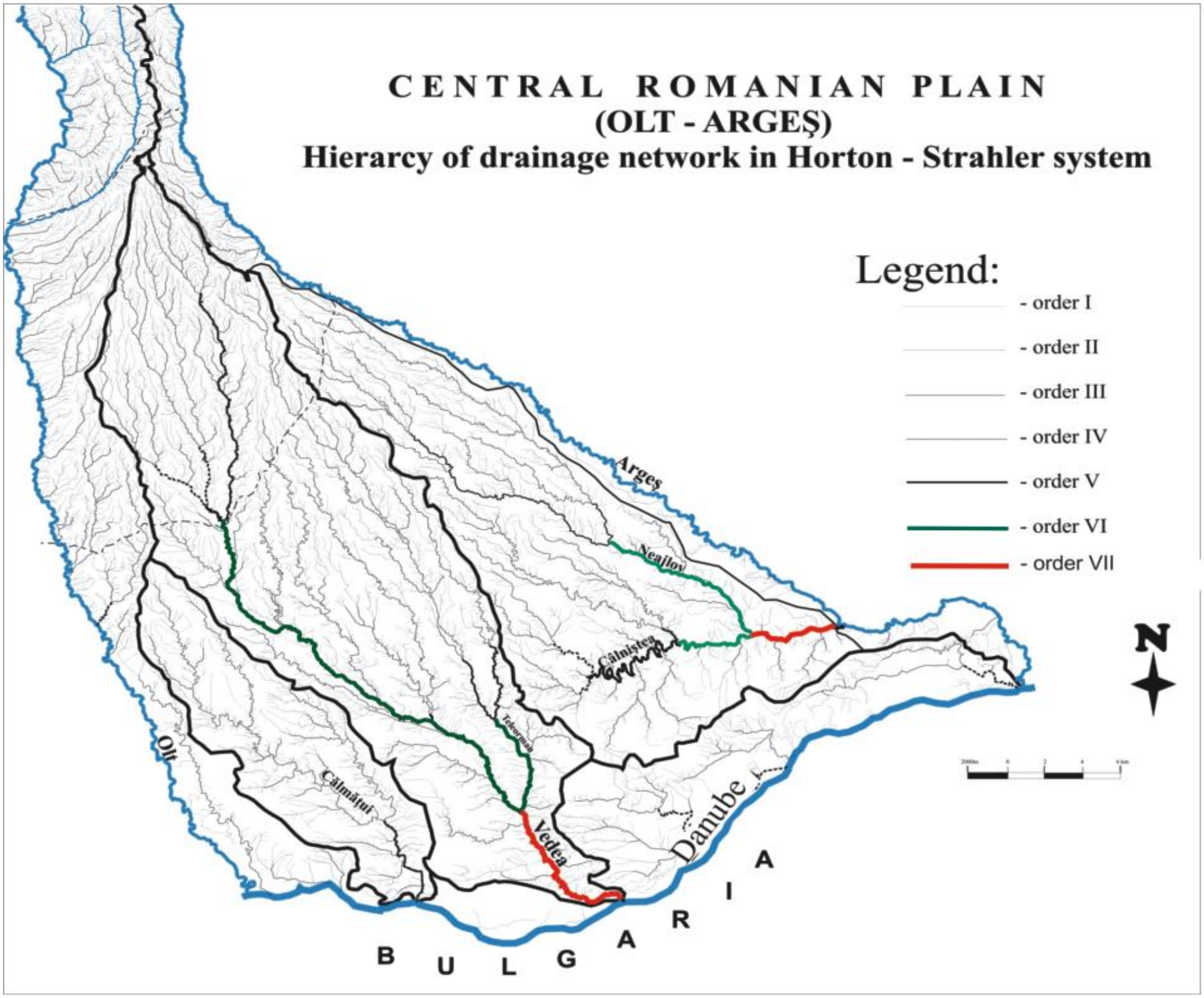

Figure 2. Central sector of the Romanian Plain and in the Getic Piedmont – hierarcy of drainage network in Horton-Strahler system.

and it drains a distance of approximately 200 km in the Romanian Plain. The hydrographic basin area is 5342 km^2 (Table 1).

The mainstream river within the Neajlov hydrographic basin, autochtonous to the Romanian Plain, has its spring in the upper part of the Argeş alluvial fan (at 258 m altitude) (Piteşti terrace plain). The upper stream dissects the flat tops of the Argeş terraces t_2 and t_3 (Rădulescu, 1956) and flows into the Argeş near Comana after crossing the terminal piedmont Plain of Găvanu-Burdea. The master channel has a length of 177 km and drains together with its tributaries (Dâmbovnic and Câlniştea) an area of about 3720 km^2.

The Calmatui River springs from the Boianu Plain at 158 m altitude and flows into the Danube trough Suhaia Lake at approximately 20 m altitude. The total length of the main river is about 143 m and together with its tributaries (Calmatuiul Sec, Sodol, Urlui) it drains an area of about 1370 km^2. The major feeding source of the mainstream rivers of these catchments and of their tributaries in the upper drainage basins is represented by the alluvial deposits (of piedmont origin), which are rich in groundwaters. This explains the relatively high density of the drainage network in these hydrographic basins (Figure 2).

Geological conditions, but especially the hydrogeological ones (the depth of water table and the hydraulic gradient) specific for the investigated basins influence to a high extent the drainage regime. Rivers derive their waters from underground sources in various proportions,

Table 1. Morphometric parameters of the rivers.

Drainage basin	Surface, (kmp) (after Raurile, 1971)	Alt. max (m)	Alt. min. (m)	L river (km)	Sinuozity index (k)	River slope (m/km)	Concavity index (I_C)	Liquid flow (Q) (after Raurile, 1971)	Stream frequency N_1/F	Draiange density ∑L/F	Horton-Strahler order
Vedea	5342	550	20	251	1.98	2.11	0.54	13.9 m3/s (Cervenia)	1.98	2.34	7
Neajlov	3720	258	43	177	1.5	1.2	0.26	8 m3/s (Calugareni)	0.57	1.32	7
Calmatui	1375	158	20	143	1.84	0.96	0.18	1.07 m3/s (Crangu)/1.6(la varsare)	1.04	1.26	5

which differ from west to east (from 20 to 25% in the case of the Vedea and Neajlov rivers to 15% for the Mostiştea) (Geografia, 2005). All the three rivers have their springs in the alluvial deposits (which are in fact the alluvial fans of some former large rivers deposited at the foot of the Getic Piedmont or Subcarpathians).

The rivers in the central part of the plain (Vedea, Neajlov) are characterized by a dense drainage network due to hydrogeological conditions offered by the Frăteşti Gravels in the south and the piedmont deposits (Cândeşti Gravels) in the north. This is proved by the high value of the confluence ratio for lower order stream segments [Rc_1 = 5.56 – Cotmeana (Trybutari river of Vedea)]; Rc_1 = 5.15 – for Neajlov; Rc_1 = 5.73 for Vedea = 5.73) unusual situation for a plain river, explained by the demonstrations of Schumm et al. (1995) regarding the genesis of the rivers of Stepheads type.

METHOD AND DATA COLLECTION

The present study made use of complex methods. The demonstrative method is the geomorphometric one and is based on the Horton-Strahler hierarchic system (Figure 2). The field observations and the researches performed in the period 2004 to 2009 consisted in cross profile analyses, the mapping of the river system and the channels' specific features, the study of the topographic maps of scales 1: 100 000, 1: 50 000 and 1: 25 000 (editions 1970, 1972 and 1997), and their comparison with the orthophotos of scale 1: 5 000 (editions 2005 and 2006) for the study region, in order to get familiar with the situation in the field and to map the streams that are not shown on the existing topographic maps. At the same time, thematic maps (geological and hydrogeological) of different scales, georeferenced by means of GIS software, were employed.
The values of the morphometric parameters, which come from direct measurements on topographic maps (scale 1: 25.000), were compared to the real values measured in the field. The following morphometric elements have been statistically processed (in order to obtain a drainage morphometric model) (Zăvoianu, 1978, 1985; Grecu, 1980, 1992, 2008):

- Order of stream magnitude: confluence ratio R_c (Hirsch, 1962); index of stream completion I_r (order of basin magnitude);
- The elements of length: total cumulative length of stream segments R_L (Horton, 1945; Strahler, 1952); ratio of average lengths R_l (Horton, 1945; Strahler, 1952); completion index of cumulative lengths I_L; completion index of average lengths I_l (Grecu, 2004, 2008).

The drainage pattern is controlled by the following three progressions: a) the progression that takes into account the number of stream segments; b) the progression that takes into account their total length, and c) the progression that refers to their average length.

The results obtained verify the law of stream segments, which says that "the number of stream segments of successively higher orders tends to form a geometric series, beginning with N1, which is the number of the 1st order streams, and decreasing according to the confluence ratio R_c" (Zavoianu, 1978; Grecu, 1980; Ichim et al., 1989) (Tables 2, 3 and 4). The geometric progression of the number of streams proves the dynamic balance attained by the catchment during its evolutionary stages, in response to the physical setting and to the transfers of information, substance and energy occurring within it.

By measuring on the map the length of each segment and by adding up the values obtained for each stream order we have come up with a dataset, which plotted on semi-logarithmic coordinates obeys the law that can be stated as follows: "the average length of stream segments of successive orders tend to form a geometric series beginning with the average length of the 1st order segments (L_1) and decreasing according to the total length ratio *(R_L)*" (Zavoianu, 1978; Grecu, 1980; Grecu, 1992; Grecu and Palmentola, 2003).

In order to establish the stages of valley development, profile concavities were computed for the main investigated valleys (Munteanu et al., 1991; Radoane et al., 2000, Molin et al., 2011), by using the following formula:

$I_C=A_1/A_2$

Where I_C is index concavity; A_1 is the area lying between the line of profile and the diagonal that links its ends; A_2 is the area of the triangle formed by the previously mentioned diagonal and the projection of stream length on the horizontal axis.

The value of this ratio allows the estimation of the valley shape. Thus, the values close to 0 mean a rectilinear profile, while those close to 1 suggest either a positive or a negative convexity. The present study wants to demonstrate the fact that the great density of the drainage network in the central part of the Romanian Plain is due to its geographic position oriented towards the piedmont detritus deposits as well as to identify the morphometrical and morphological parameters of the actual riverbeds and their influence as result of evolution.

Geological characteristics and drainage network

Geological conditions, especially the hydrogeological ones (groundwater's depth and flow) that characterize the study

Table 2. Morphometric data for the drainage model of the Neajlov River (after Vacaru, 2010).

Parameter	Measured M / Calculated C	Order of magnitude N1	N2	N3	N4	N5	N6	N7	Ratio	*Ir* (%)
Number of river segments (*N*)	M	2136	415	75	16	4	2	1	R_C=3.89	I_N=27%
	C	941.8	242	62.2	16	4.1	1.05	0.27		
Cumulative length of stream segments *L* (km)	M	-	901.7	514.2	316.5	166.9	66.6	24	R_L=2.1	I_L=34%
	C	2930.9	1395.7	664.65	316.5	150.7	71.76	34.17		
Average segment length (*l*) (km)	M	-	2.2	6.9	19.8	41.7	33.3	24	R_l=1.85	I_l=56%
	C	3.13	5.8	10.7	19.8	36.63	67.7	125.2		

M, Measured (value resulted from counting and direct measurements on topographic maps); C, calculated (values obtained by multiplying or dividing the number of streams by Rc: for instance, N_4 x Rc = N_3, or expressed in figures 16 x 3.89 = 62.2) (Zavoianu, 1978; Grecu, 1980).

Table 3. Morphometric data for the drainage model of the Vedea River.

Parameter		Order of magnitude N1	N2	N3	N4	N5	N6	N7	Ratio	Ir (%)
Number of river segments (*N*)	M	10627	1853	353	63	14	3	1	R_c=4.8	I_N=63
	C	7642.56	1592.2	331.7	69.1	14.4	3	0.63		
Total cumulative length *L* (km)	M	7880	1900.35	1222.3	795.45	312.1	388.4	155	R_L= 2.2	I_L=41
	C	7310.8	3323.1	1510.5	686.6	312.1	141.9	64.5		
Average length *l* (km)	M	0.7	1,03	3.5	12,6	22.3	129.5	155	R_l= 2.9	I_1=121
	C	0.3	0,9	2.7	7.7	22.3	64.7	187.6		

M, Measured; C, calculated.

Table 4. Morphometric data for the Cotmeana river (Vedea basin) drainage pattern.

Parameter		Order of magnitude N_1	N_2	N_3	N_4	N_5	Ratio	*Ir* (%)
Number of river segments (*N*)	M	1107	199	37	5	1	R_C =5.84	$I_{N=}$ 86
	C	995.9	170.53	29.2	5	0.86		
Summated segment length L (km)	M	559.5	248.5	111.5	47.5	55.5	R_L =1.92	$I_{L=}$ 54
	C	411	214	111.5	58	30.2		
Mean segment length (*l*) (km)	M	0.51	1.25	3.01	9.5	55.5	R_l =3.47	$I_{l=}$ 60
	C	0.22	0.79	2.74	9.5	33		

M, measured; C, calculated.

basins, influence very much the drainage regime. The typical deposits of the central sector of the Romanian Plain consist in porous permeable rocks, respectively of Pleistocene and Holocene gravels and sands.

The Cândeşti strata, characteristic for the Getic Piedmont, extend also in the plain, being found in relatively small areas, especially at the contact plain - piedmont. They are made of alluvial-lacustrine deposits composed of tens of meters thick stacks of gravel alternating with marl-clays and sands. In piedmont deposits, the groundwater is located at depths of over 50 m in, due to the gravel strata.

Groundwater drainage towards the contact with the plain and within the plain area leads to saturation of psephite deposits generating aquifers that flow out and springs that feed the rivers within the plain area (Liteanu, 1969). The Frăteşti strata lying south of the Piteşti-Slătioarele alignment are located under loessoid deposits at depths of 20 to 25 m. At these depths, the groundwaters are unconfined and their flow direction from northwest to southeast is complying with the hydrographic network (within the plain territory comprised between the Jiu and the Argeş). The Mostiştea sands appear east of the Argeş and display an average grain size, the hydrostatic level ranging between 5 and 20 m, being influenced by the presence of sandy clays and sand deposits (low flow, below 1 l/s) (Liteanu, 1969).

Under these conditions, the rivers are moderately fed by underground sources, although aquifers are very rich for a plain zone. Significant variations are displayed from west to east (20 to 25% for Vedea and Neajlov) (Geografia, 2005). The rivers in the central part of the plain (Vedea, Neajlov) are characterized by a dense drainage network (Table 1). However, in the eastern sector the density of drainage network has low values (in the Mostiştea catchment it is of 0.14 km/km^2) also due to the decreasing annual average amount of precipitation, which barely reaches the value of 500 mm. From this point of view, the climate is having an excessive character (Bogdan, 1999; Dragotă, 2006).

RESULTS

The geomorphometry of the drainage network

All the three rivers spring from the alluvial deposits (alluvial fans of large rivers lying to the outer part of the Piedmont or the Subcarpathians). This observation is also supported by the high value of the bifurcation ratio for the low order segments (Rc_1 = 5.51 – Cotmeana), an abnormal situation for a plain river but explained by the demonstrations of Schumm et al. (1995) on the formation of the rivers of stepheads type (demonstrated the role of groundwaters in the formation of stepheads by bringing the argument of the higher bifurcation ratios of 1^{st} and 2^{nd} order streams compared to those of 3^{rd} and 4^{th} order).

According to the hydrographic network hierarchy in Horton-Strahler system, the river Neajlov is of 7^{th} order after the junction with the Câlniştea, it is the largest tributary, but in the upper course upstream the junction with the Dâmbovnic, the Neajlov is only a 4^{th} order stream (Figure 2). The Vedea River becomes a 7^{th} order segment immediately the downstream of its junction with its largest tributary, the Teleorman; as far as the Cotmeana is concerned, which is the main tributary in the upper course; this is a 5^{th} order stream.

Morphometric analysis of the Neajlov catchment

The analysis of the confluence ratio values of the low order segments and of the degree of completion of the drainage network in terms of size, total cumulative length and average cumulative length are representative for some elements on the dynamics of riverbeds.

The completion index expresses the extent of each parameter in the basin (Grecu, 2004, 2008). Thus, in the upper course, the 4^{th} order for the Neajlov is achieved in terms of the total number of stream segments (I_N = 105%), but hardly achieved in terms of the length of tream segments (I_L = 59%) or in terms of the average length of the stream segments (I_l = 56%) (Table 2) (Vacaru, 2010). This demonstrates the high degree of terrain fragmentation in this plain sector with an average confluence ratio (R_C) of 6.63 which is an atypical tendency for plain rivers (Grecu et al., 2009b) (Figure 3).

The torrential character of the river segments is owed to the incompletion of cumulative length. Most of them are 1^{st} and 2^{nd} order segments, respectively coves and gullies with average lengths between 1 and 4 km, having intermittent flow. Their occurrence is mainly due to the geological substratum (sedimentary, rotten, poorly consolidated deposits: the Argeş terrace sands and gravels -t_2, t_3, loessoid deposits, loess) and to the relief shaping processes (rain-wash, torrential processes, down-sagging and piping). These results should be corroborated with the genesis and evolution of the hydrographic network of the Neajlov catchment. The Neajlov, a local medium-sized plain river, originates in the alluvial fan of the Argeş, in which the river has carved some terraces, on which the course of Neajlov (on t_3 and t_2) and its tributaries, namely Dâmbovnic (on t_4) was outlined. An asymmetry of the basin can also be noticed, as it has developed mainly on the right side where most numerous and the longest tributaries are found. On the left side, their number is low because of the basin's hydrographic network genesis and evolution and also due to the proximity of the Argeş River. Thus, the aquifer based its source mainly on Carpathians and Subcarpathians. In the case of the Neajlov River, there is a direct link between the annual average amount of precipitation and the annual average. The high flow rates occur in the rainy years, while the low ones are specific for the dry ones (that is 1989-1990). The annual average flow in the medium-upper stretch of the Neajlov (Moara din Groapa/The Mill in the Pit) is 1.3 m^3/s, reaching 4.09 m^3/s only 30 km downstream (Vadu Lat) and approximately 8 m^3/s some other 40 km downstream (at Călugăreni gauging station) (Pişotă and Cocoş, 2003). The flow values are also maintained by the discharge of the aquifer layer.

The morphometric analysis based on the Horton-Strahler system of the entire Neajlov catchment (a 7^{th} order stream) (Table 2) has led us to the following conclusions:

(i) The confluence ratio is high both for the low order segments (Rc_1 = 5.73) and for the entire catchment (Rc = 3.89) (Table 2). This is due to the relatively low average lengths and the R_1 values (1.85) (Table 2);
(ii) On the whole, the Neajlov catchment is underdeveloped both in what concerns the number of stream segments (I_N = 27%) and with regard to the total (I_L = 34%) and average (I_l=56%) lengths;
(iii) By corroborating the drainage density (1.32) and the concavity index (0.26) one can conclude that with a size order of 7, the Neajlov River could be in fact a successor

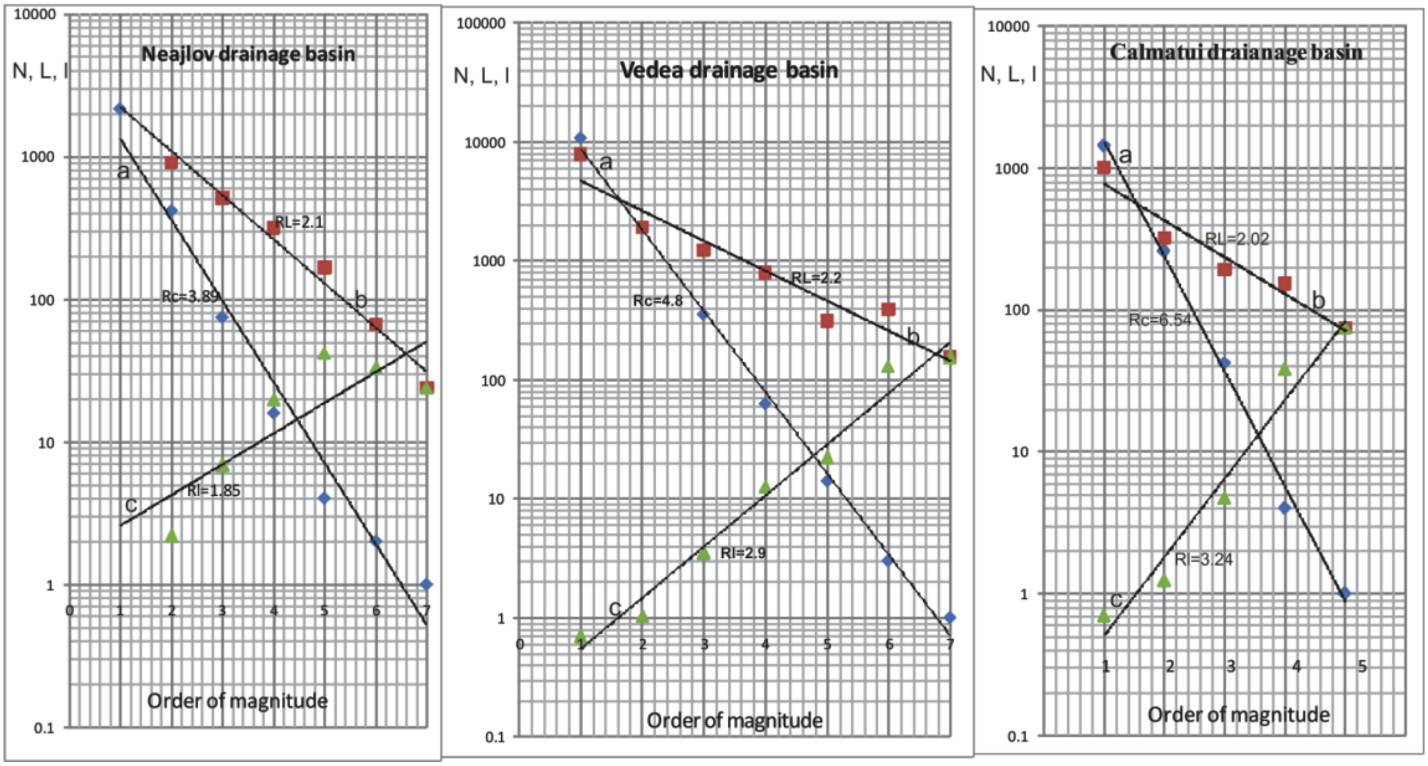

Figure 3. Drainage morphometric models of Neajlov, Vedea and Calmatui Basins a - law of stream number; b – law of summated lengths, c – law of average lengths.

of a former river originating in the Carpathians or the Sub-Carpathians (Figure 4).

Morphometric analysis of the Vedea catchment

The Vedea River is the mainstream of its catchment. From its springs till its confluence with the Danube, the river crosses the Cotmeana Piedmont and marks the geographic limit between the Boianu and Burdea Plains (more exactly between the Iminog Plain in the north and the Urului Plain in the south). Downstream its junction with the Teleorman highlights the geographic limit between the Boianu Plain (Urului Plain) and the Burnas Plain. The river is formed by over 12900 different organisms of different orders with a cumulative length of over 12600 km. It is made up of a series of very big sub-catchments located on its left side (Cotmeana and Teleorman) and of some big ones located both on its left (Vediţa, Tecuci, Burdea and Valea Câinelui) and on its right side (Plapcea, Dorofet, Nanov Geamăna).

By analyzing the table of the drainage model and the graph, one can notice that the Vedea is a 7th order river, having a bifurcation ratio of 4.8 and a completion index of 63%. The most active are the 1st and 2nd order streams, summing up 10600 segments and displaying a higher frequency in the upper basin. The cumulative length of the two size orders is approximately 9700 km, with an average of 0.7 km for the 1st order and 1.03 km for the 2nd order streams. Out of the 1853 second-order branched out torrential streams, over 1100 supply directly with materials the superior segments while the rest help the formation of 3rd order segments by unifying the transported material. The 3rd and 4th order streams are considered to be intermediary segments of transport. They sum up over 400 segments displaying a cumulative length of more than 2000 km and an average length of 3.5 km for the 3rd order and 12.6 km for the 4th order. Among the 353 3rd order segments, over 200 provide a direct material supply for the high order segments and over 120 contribute to the formation of the 4th order segments.

The junction of the Vedea, a 6th order segment, and the Cotmeana River, located at more than 150 km towards its junction with the Danube, makes the Vedea become a 7th order stream, due to the important amount of materials brought by the Cotmeana.

The total cumulative length ratio is 2.2 and the average length ratio is about 2.9. The completion index is 41% and in the case of the average lengths 121% (Table 3). The Vedea morphohydrographic catchment is not completed if considering the number of segments of different orders and the cumulative length. It results a high dynamics for the 1st and 2nd order streams, which by

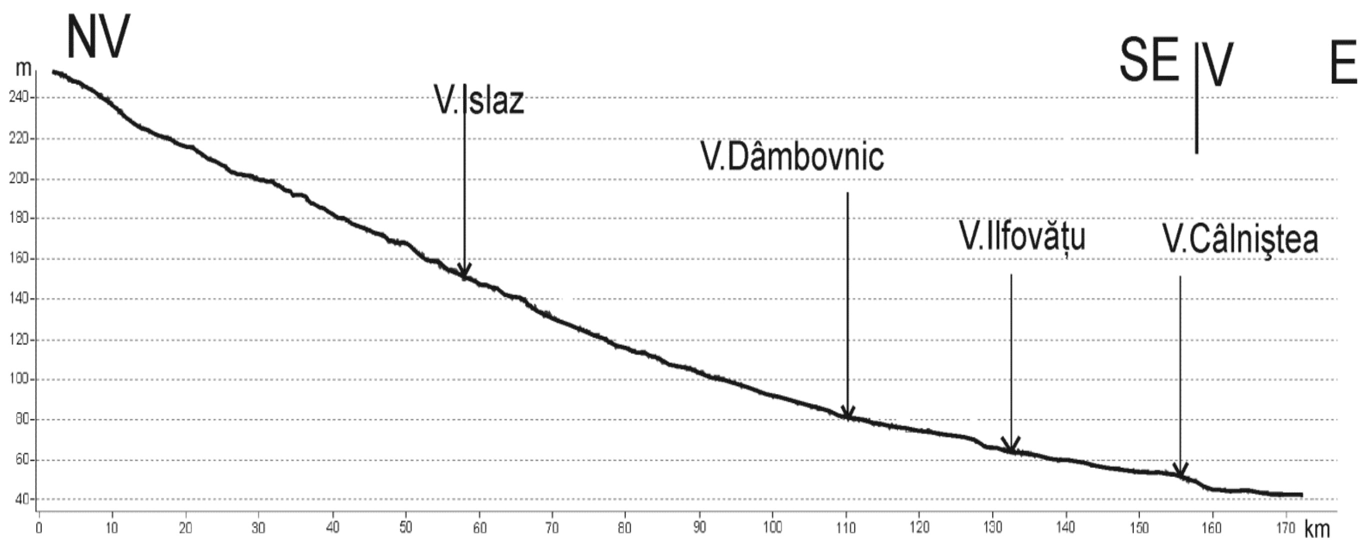

Figure 4. The Neajlov River- longitudinal profile.

headward erosion against the highlands are able to branch off, changing their final order and also the cumulative length for all the orders. In the middle part of the basin length enhancement can be achieved by lateral erosion (meandering) which leads to the increase of major riverbed areas. As far as the average length is concerned, the basin has an index of 121%, which indicates a small over dimensioning if compared to the optimum value of 100%. This suggests that the basin has a general tendency of reaching the equilibrium profile.

As far as the Cotmeana River is concerned (which is a tributary of the Vedea in its upper course), it derives its waters from the piedmont and therefore should be looked upon as a contact river, with middle and lower courses within the plain area. On the whole, the Cotmeana morphohydrographic system is incomplete, but highly dynamic, especially in the case of the 1st and 2nd order segments, which might change in the future their size order due to the headward erosion.

The values of the subsystems' development parameters show a stagnation of the magnitude orders on the left, where Cotmeana receives the waters of its tributary, the Vârteju and a higher dynamics on its right side. The parameters also highlight a dynamic subsystem on the western slope of the basin due to the headward erosion exerted by the 1st and 2nd order torrential streams (Table 4). At the contact between the piedmont and the plain the Cotmeana is fed by many springs, which are responsible for the largest partially bifurcation ratio: R_{C3} = 7.4 (N_3/N_4 = 37/5 = *7.4).*

Morphometric analysis of the Calmatui River

The Calmatui catchment, which lies entirely in the Romanian Plain, has the following specific features:

(i) The catchment is underdeveloped (Ir = 63%) from the standpoint of the total stream length, whereas Rc is 6.4 (Table 4), a value rather high for a plain area. This could be explained by the large number of 1st and 2nd order streams which account for 97.28% of the total number of stream segments (Figure 3);
(ii) The average length of the 1st order segments is 0.7 km which means double in comparison with the other two investigated catchments (the Vedea and the Neajlov). Seemingly, many such minor streams have resulted in the process of the draining of the loess sinkholes and microdepressions;
(iii) The development degree judged from the point of view of the average length is 66%, while the R_1 ratio is 3.24. The highest deviation from this trend line is observed in the case of the 4th order streams, whose real length is much higher than the computed one;
(iv) The values of the concavity index mirror the low gradient, which is typical for a plain stream (Figure 6).

Conclusions

The investigated rivers have not only similar, but also different geomorphic characteristics which are due to their geographical position and to the evolution stage. Geomorphometric analysis in Horton-Strahler system clearly reflects these differences, as follows:

(i) The confluence ratio in the upper section of the Vedea catchment (at the contact between the plain and the piedmont) is high;
(ii) The riverbed of the Neajlov River is oversized (probably because it has inherited an old riverbed, initially belonging to a former Subcarpathian river). In addition,

Table 5. Morphometric data for the Calmatui River drainage model.

Parameter	M/C	Order of magnitude					Ratio	*Ir* (%)
		N_1	N_2	N_3	N_4	N_5		
Number of river segments (*N*)	M	1426	258	42	4	1	R_c = 6.54	I_N =98
	C	1796.4	274.68	42	6.42	0.98		
Summated segment length L (km)	M	1003.29	320.29	192.79	152.77	74.84	R_L = 2.02	I_L= 63
	C	786.59	389.40	192.79	95.44	47.25		
Mean segment length (*l*) (km)	M	0.70	1.24	4.69	38.10	74.84	R_l =3.24	I_l = 66
	C	0,45	1.44	4,69	15.20	49.25		

M, measured; C, calculated.

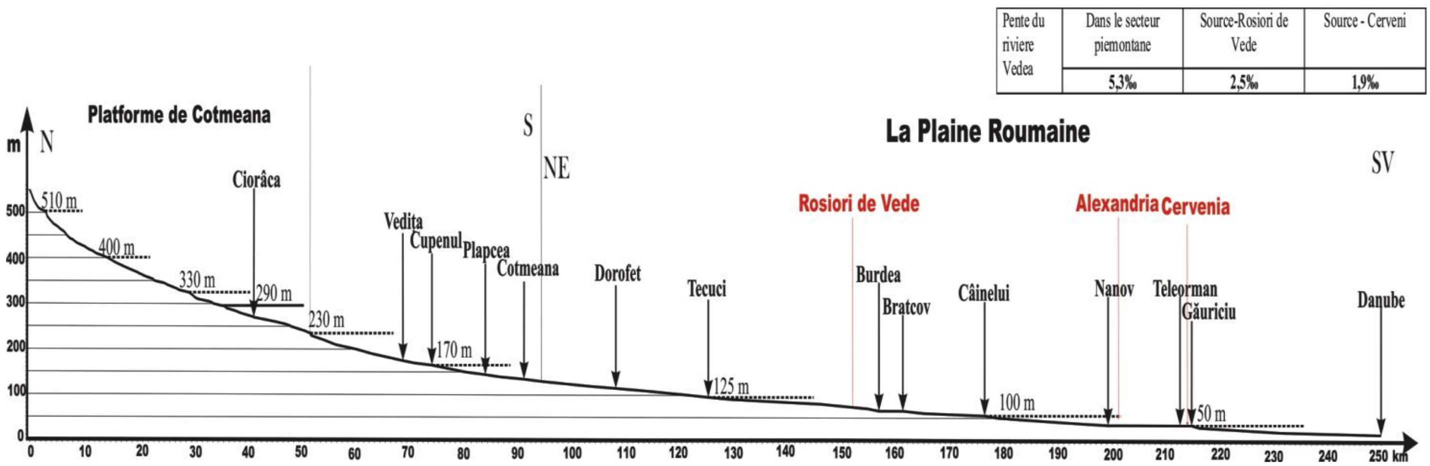

Figure 5. The Vedea River – longitudinal profile.

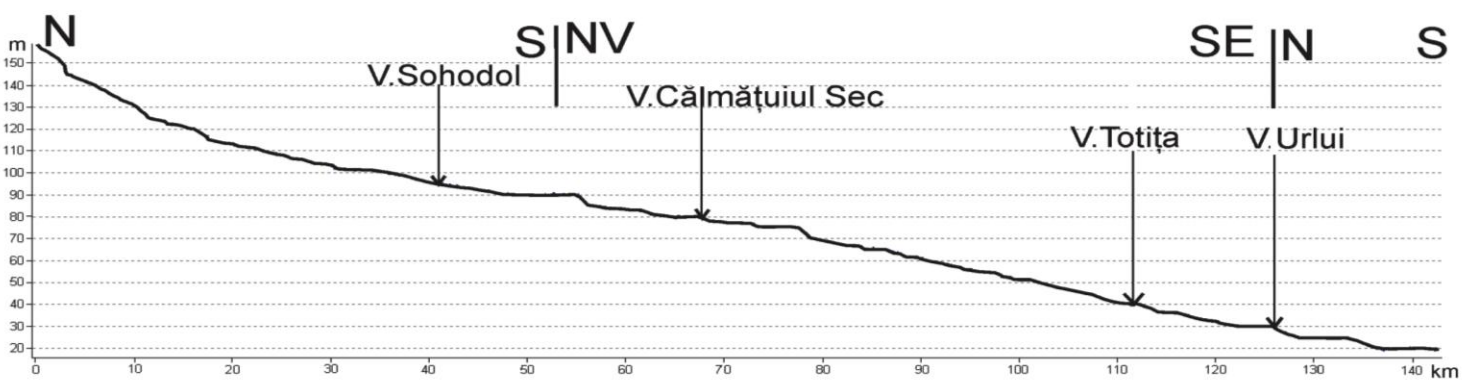

Figure 6. The Calmatui River – longitudinal profile.

the river is richly fed by the groundwaters stored by the Argeş alluvial fan deposits);

(iii) The length of the 1st order streams belonging to the Calmatui River is oversized due to the complex compaction and piping processes, which are mirrored by the linear development of the microdepressions;

(iv) The concavity index of the plain streams does not show variations, indicating different stages of evolution as it happens with the streams crossing several landform units (Molin et al., 2011; Radoane et al., 2010) (Figures 4, 5 and 6).

The analyzed rivers are tributaries to the Danube (in its lower course), whose level changes affect the dynamics of its tributaries' riverbeds (Valsan, 1916). The processes of vertical cutting and regressive erosion are analyzed through the number and length of the river segments, while lateral cutting is reflected by the meanders' morphometry (Grecu et al., 2010).

The study demonstrates the importance of morphometric methods in the analysis of relief dynamics and evolution in the studys of hydogeomorphological hazards.

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