THE CODIFICATION OF THE RIVERS NETWORK AND BASINS FROM THE SĂRĂȚEL MORPHO-HYDROGRAPHIC SYSTEM (BUZĂU)

Nicolae Cruceru, Gheorghe Herişanu
"Spiru Haret" University of Bucharest, crucerunick@yahoo.com

Abstract. The codification of the fluvial network within the Sărățel morpho-hydrographic Basin displays the typology approached by Gravelius, a coding system used in the Romanian Waters Cadastre; subsequently, the coding proposed by Pfafstetter is presented, as it is used for large and small rivers as well as for basins and sub-basins. Both systems start the classification from the main course to the smallest rivers. This contribution proposes a new coding system for Sărățel basin, based on the Horton – Strahler classification, which starts from the small arteries of the first order, to the greatest one, of a superior order, a classification elaborated and used by Zăvoianu et al. (2010). The new system can be adapted to GIS and starts from simple to complex, from small to large, respectively. The new aspect consists in the fast spatial identification of the sub-basins along with the achievement, the development and utilisation of a database created during the codification. The system can be recommended for detailed studies, in small and large hydrographic basins.

Keywords*: *morpho-hydrographic basin, codification, Sărățel

Introduction

Geographical research is increasingly more dominated by technology, instruments and methods that are based on databases retrieved in the field or modelled with modern applications. Global development is at all levels influenced by current requirements in environmental research, risks and natural hazards investigation, among which the denudation processes on well-defined areas are included, requesting from the researchers new instruments and methods for the quantification of the natural phenomena, in order to design scenarios and predictions or to elaborate possible decelerations in the evolution of extreme events. In the last decades, the reference units most often used by hydrologists have become "study areas" for geomorphologists as well, especially for monitoring slope processes, fluvial dynamics, natural hazards and risks, etc. This is due to the facile quantification of the inputs and outputs of a morpho-hydrographic system. Grecu Florina and Zăvoianu I. (1997) summarized the studies concerning hydrographic basins (nationally and internationally reported) in Revista de Geomorfologie no. 1. S. Mehedinți and G. Vâlsan first introduced the concept of hydrographic basin to the Romanian geographical literature at the beginning of the XXst century, while after 1950, S. A. Munteanu (1956), M. Moțoc (1963) and others have developed practical studies on torrential basins. The studies focusing on hydrographic basins are increasing after 1970, both at theoretic level (Posea et al, 1976, and, more recently, Rădoane 2002) and in practice (Aurora Posea, I. Zăvoianu, Florina Grecu, Armaş Iuliana, Maria şi N. Rădoane, M. Ene, A. Nedelea, N. Cruceru, S. Bănică, R. Pițigoi and others). The numerous studies need fast and accurate approaches in data analysis and in their representation. Thus, the Geographical Information Systems (GIS) entered this study domain as a method of data quantifying and modelling, especially in their graphical and cartographical representation. A large number of attributes of the river network and of the related basins can be registered in the working database, through GIS programs, and, subsequently can be easily processed, interpreted and represented. The practical requirements related to the quantification of the data collected in the field or resulted from the processing of topographic maps, satellite images or ortophotomaps meet some restrictions in using the existing classifications and codifications of the river network and related basins. Thus, a new classification and codification manner is intended, in order to ease the localisation of the reference units by GIS (Zăvoianu et al, 2010), for the needed basins, the sub-basins and the surfaces within the basin, or for those chosen for a certain purpose. Therefore, besides the existing coding systems implemented by Pfafstetter, Lawa, Li, Briton and others, a new coding can be added, based on the Horton-Strahler classification (Zăvoianu et al, 2009) (Fig. 1).

First, there are the systems that start from large to small according to Gravelius's classification, assigning the first order to the main course, the second order to the rivers flowing in the first, and so on to the smallest arteries that may have different orders, depending on their position in relation with the main river and irrespective of the surface of the basins. Hence, there can be noticed that the smallest water arteries can belong to the second-order rivers that flow directly into the main watercourse, as well as in the highest order. The second type of systems starts from the smallest watercourses which are considered in the first order of the Horton-Strahler system, towards the major river which is, in all cases, of the highest order. This system, which follows up the structure and the genetic classification of the network, from small to large and from simple to complex applies to the Sărățel basin, in the case of which it is exemplified.

Results and discussions

The Sărățel basin is tributary to the Buzău River, in the area of the Buzău Sub-Carpathians. It drains a total surface of 189.54 km^2, with altitudes ranging from 935.4 m (in Plaiul Nucului from the Ivănețu Hill) to 141.6 m, at the confluence with Buzău River (Cândeşti accumulation). The river has a length of 34.21 km and it presents an average multiannual debit around $1m^3/s$. Current modelling processes are intensely active within this morpho-hydrographic basin, as a consequence of the physical-geographical and anthropic conditions. A number of 5261 river segments were inventoried, counting around 1565.67 km. The total divides in 4162 first-order river sectors and 837 second-order sectors, which represent rivers with an elevated erosion and transport potential, described as torrential. This type of data, and not only, can be collected and used for different impact studies, if a suitable coding system exists, by which the spatial position and source of the rivers and/or of the related basins could easily be determined.

The codification of the basins in the Romanian Waters Cadastre

The Gravelius classification was the basis for coding the hydrographic basins in the Waters Cadastre, from the main courses to which the first order was assigned, to the most distant and ramified compared to the main course, that have received increasingly higher orders. Thus, three collectors were established nationally (Tisa, the Danube and the Black Sea), from which the first order was attributed to the main tributaries. Romania was divided in this way in 15 hydrographic systems codified with Roman numerals, from I to XV. From this point, the coding followed the same criteria (from small to large) to the sixth order. In the cadastre, the Sărățel basin has the code XII.82.25, which means: XII for the Siret basin, 82 for Buzău basin and 25 for Sărățel (Berca). If this coding is continued, it will be noticed that a magnitude order may include tributaries with significant length and basin-surface differences, even if it is only a ranking of the sub-basins in report to the main watercourse.

The Pfafstetter codification

This system is theoretically based on rigorous principles, among which: the main course drains the entire surface; the first four tributaries with the greatest surfaces from the major basin receive the codes (even numbers) 2, 4, 6, 8 from downstream to upstream; the free space is divided in five intra-basin surfaces coded as well from downstream to upstream (uneven numbers) by 1, 3, 5, 7, 9; to continue the coding for the tributaries and the intra-basin surfaces, the above mentioned steps are repeated (Zhang et al, 2007, cited in Zăvoianu et al, 2010). By applying this classification system to Sărățel basin, considered a first order basin (without taking into account the superior levels of Siret and Buzău rivers), the coding will be made depending on the report between the tributaries length and the surfaces: 12 – the Băligoasa basin, 14 Grabicina, 16 Slănicel and 18 Strâmbu (Şuchii) (Fig. 2a).

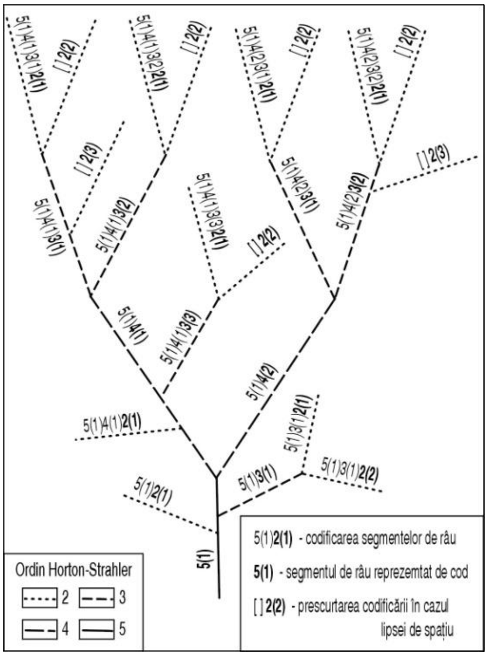

Figure 1 The coding scheme proposed by Zăvoianu I. (2009), on the basis of the Horthon-Strahler classification

The five remaining inter-basin surfaces will be coded with uneven values: 11, 13, 15, 17 and 19. For the following coding level each coded basin and inter-basin is analyzed and,

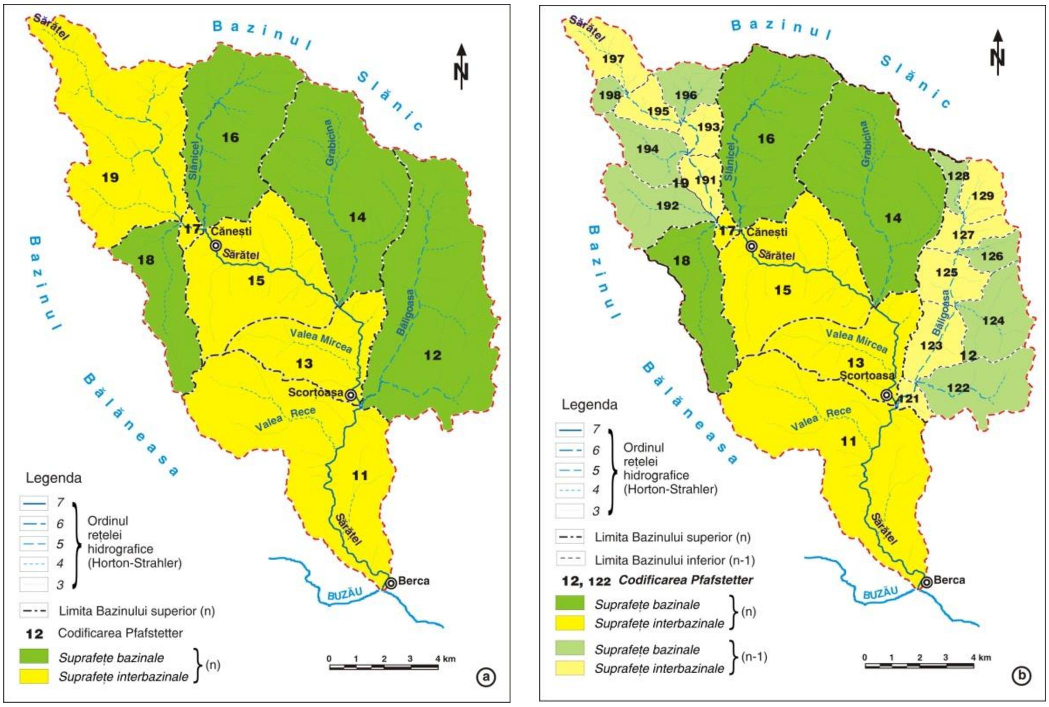

Figure 2 The Pfafstetter codification applied within Sărățel hydrographic basin

according to the requested degree of detail, the individualisation of another level is started. Thus, in the basin of Băligoasa stream, as there are four large tributaries, the code 122 will be applied to Pâclei Valley basin, 124 to Arbănaşului Valley, 126 to Corbului Valley, 128 to Mitoc Valley, and, correspondently, there will be five inter-basin spaces left, noted with 121, 123, 125, 127 and 129 (Fig. 2b). The basinal space 122 can be detailed with an even coding for sub-basins (1222, 1224, 1226 and 1228) and uneven for inter-basins spaces (1221, 1223, 1225, 1227 and 1229). For the interfluvial space with the code 19, a coding of the direct tributaries can also be made, with the code 192 for Strâmbu Şuchii basin, 194 for Lalu Valley, 196 for Creveleşti and 198 for Potecu. Taking into consideration the levels approached, the study can be taken to a new degree of detail. For example, other sub-basins and inter-basin spaces that can be encoded are identifiable in the Strâmbu Şuchii basin (1922, 1924, 1926, 1928 – for sub-basins and 1921, 1923, 1925, 1927 and 1929 – for inter-basin spaces). Likewise, other sub-basins can be identified, as direct tributaries of other coded watercourses. The system has an appreciable degree of detail and can be used in a thorough analysis, even if, in these case as well, it is only valid for placing that area within a certain hydrographic system. The possibilities are limited by the 9 numbers involved at each level (4 in the category of basins and 5 for inter-basins) and do not allow the inclusion of other basins and sub-basins with similar surfaces in the respective category, as the later will be included in the next coding level. None the less, the limited number of figures, from 0 to 9 for each level, facilitates the coding process and does not require a split for each level.

The codification based on the Horton-Strahler system (proposed by Zăvoianu I.)

The necessity of studying the morphometric characteristics of the rivers network and of the hydrographic basins and their spatial positioning imposes the introduction of a coding system that will meet the following conditions (Zăvoianu et al., 2010):

- to allow the delimitation, positioning and access from the database of any segment or basin, irrespective of the magnitude order;
- to ensure the database for the statistical processing of the morphometric elements of the rivers network and hydrographic basins at the main confluences, at hydrometric stations or in different points chosen from the longitudinal profile;
- to correspond to the classification system proposed by Horton-Strahler;
- to allow the grouping and analyse of the morphometric characteristics on magnitude orders;
- to be usable even if the coding is not completed to the basin of the highest order, being accomplished only for a series of sub-basins;
- the system is useful for detailed studies and it can be implemented after the classification of the rivers network and hydrographic basins by digitizing or automatic processes on maps at a scale of 1:25000 or on a high resolution digital terrain model.

When the digitization is manual it is recommended that the smallest basin units outlined to be of the second order, if necessary the first order ones being available from calculations. It is more suitable to begin with the second order, because it is easier to distinguish the starting point at the confluence of two first order river segments. If the start is from the first order, the starting point is very difficult to position on the map, even if the confluence point can be distinguished from the contour lines configuration, and, in the end, the obtained length values will be under-evaluated or overstated and the working time doubles. Digitizing is always made from upstream to downstream, on the sailing line of the river segments (Zăvoianu et al., 2010).

From the union of two second-order segments it results a third-order one and the ranking continuous to the highest order that ends in a confluence or flowing mouth. In the case of Sărățel River, the digitization and ranking accomplished for the entire river segments network has reached the seven-order for the main course, an order that corresponds to the segment from the confluence with Slănicel stream on the left side, to the confluence with Buzău River (Cândeşti accumulation). Consequent to the digitizing of the river segments of different magnitude orders from upstream to downstream, the delimitation of the hydrographic basins of each order has been initiated, in this case starting from the highest order to the smaller ones. Simultaneously with this activity, the basins and the correspondent river segments of different orders were encoded in the database. It is obvious that when a basin receives a code, this code is automatically assigned to the river segment of the same order. In this case, the basin of Sărățel River receives the code 7(1) which will be held by all the sub-basins that it includes, except for the case when a codification is made for the sub-basins from the Buzău, Siret and perhaps Danube basins, when a new identity will be find for it, within these larger units. Continuing with the delimitation and codification of the six-order basin correspondent to the river segments of the same order, it is noticeable that there are three segments of this order. The first is Sărățel until the confluence with Slănicel, followed by Slănicel (left-side tributary) and Băligoasa (left-side tributary situated in the inferior half of the basin 7(1)). Thus, a rather elongated basin is outlined, receiving only tributaries of inferior orders, the skip to a superior one being made by the connection with another tributary of the same size. In this case, the code of the main course 7(1), receives the code of the first six-order sub-basin, the resulting code becoming 7(1)6(1) for Sărățel. The second six-order sub-basin is the Slănicel basin that will receive the code 7(1)6(2), which means that it is the second six-order sub-basin from the main 7(1) basin. The third sub-basin, Băligoasa, receives the code 7(1)6(3), as it is the third sub-basin of this order (from upstream to downstream). The surfaces from the seven-order basin that have remained uncodified after the code assignement for the six-order basins will be considered as sixth-order inter-basin space (Fig. 3a).

Moving on to the fifth-order basins category, their codes will also be assigned from source to river mouth in the order of the confluences. In this manner, the Sărățel basin upstream of the confluence with the Creveleşti River will have the code 7(1)6(1)5(1), while Creveleşti will be coded with 7(1)6(1)5(2) and Lalu Valley with 7(1)6(1)5(3). Subsequently, the next sub-basin of Sărățel will be the fourth from source (Strâmbu), coded 7(1)6(1)5(4). Following the same principle, inter-basin spaces or basins of inferior orders remain. In the case of the fifth-order tributaries from the sixth-order Slănicel basin, the coding keeps the same methodology and, therefore, the Sărățel River basin upstream of the confluence with Slănicel River will have the code 7(1)6(2)5(1) Glodurile Valley River, and the later – 7(1)6(2)5(2) Chiliile River. After the coding of all the fifth-order basins, the spaces remained in the main basin will be considered fifth-order inter-basin spaces, which, summed with the surface of the fifth-order basins, will equal the surface of the major basin. There is the possibility that a fifth-order tributary directly conflates with the 7(1) order, case in which it receives the 7(1)5(1) code – Grabicina River. Therefore, the first from the source (Băligoasa Valley before the confluence with Pâclei Valley) gets the code 7(1)6(3)5(1) and 7(1)6(3)5(2) for Pâclei Valley (Fig. 3a).

For the fourth-order basins, the codification is made by assigning codes to certain sub-basins of the fifth-order basins or to direct tributaries of the sixth or seventh order. In this case as well the coding begins from the source and it is initiated with the first sub-basin of Sărățel fifth-order basin, with 7(1)6(1)5(1)4(1). The second tributary, a right-side affluent of the Sărățel River, will have the code 7(1)6(1)5(1)4(2). In the situation in which a fourth-order tributary is a direct affluent of the sixth (or seventh) order, the fifth order will be missing from the code or it will be marked as 5(0). In the same manner, the codification can be made within basins of inferior orders, depending on the required detail degree.

For practical purposes, it is sufficient that the detail degree is considered from the highest order of the main watercourse to the fourth-order, as the inferior orders, with reduced basin surfaces, are useful only in very detailed studies.

It is possible, for the seventh-order river segment to receive watercourses of inferior orders, without modifying its magnitude order. The first third-order course that flows directly in the seventh-order river will have the code 7(1)3(1), and the first second-order river will have the code 7(1)2(1), the code missing the orders 6, 5, 4 and 3, which are excluded, for simplicity, without difficulties (in the codification of missing basins). This procedure is also applied to inferior-order sub-basins when they do not receive direct affluents of a certain inferior order. For example, if in the seventh-order course flows the first fifth-order river, and in the later a third-order one, the code will be 7(1)5(1)3(1), lacking the sixth and fourth orders.

In all the cases, there are figures that give the magnitude order of the segment followed by the number of the related basin (in brackets), considered from source to confluence, which can reach significant values, depending on the watercourse.

The name of the watercourse is to be found as well in the database, if present on the cartographic support. The database corresponding to point, line or polygon vectors offers a wide range of possibilities for stocking, processing and interpreting the morphometric data of the rivers and hydrographic basins network. The polygon-type theme can receive data referring to the surface and perimeters of the basins of different orders, with the purpose of emphasizing the law of surfaces and perimeters. The hydrographic network can be represented by a line-type theme with length values of the correspondent river segments. Some values can be obtained and automatically transferred from the digital terrain model to the related vectors of the network and the hydrographic basins. For example, for the points corresponding to the river segments ends (start and end), the altitude values can be obtained and transferred, contributing, along with the segments length and level differences, to compute the declivity of each river segment and to calculate a mean slope of the entire rivers network from a given basin (Zăvoianu, 1985).

For the point-type theme, several locations can be chosen along the longitudinal profile at the main confluences or at the hydrometric stations, these locations carrying all the information concerning the morphometric elements measured upstream. The system also allows the recognition of the point-type themes based on the geographic coordinates.

The database developed in this manner gives the possibility to select, by interrogation, the basins larger than 10 km^2, so that only the ones with unaltered structure are represented or selected from the database. We consider that the surface is the key element that should be considered, as the length is an insignificant element for differentiation, because there are some round-shape basins with small lengths and large surfaces, as well as elongated basins with large lengths and small surfaces (Zăvoianu et al., 2010).

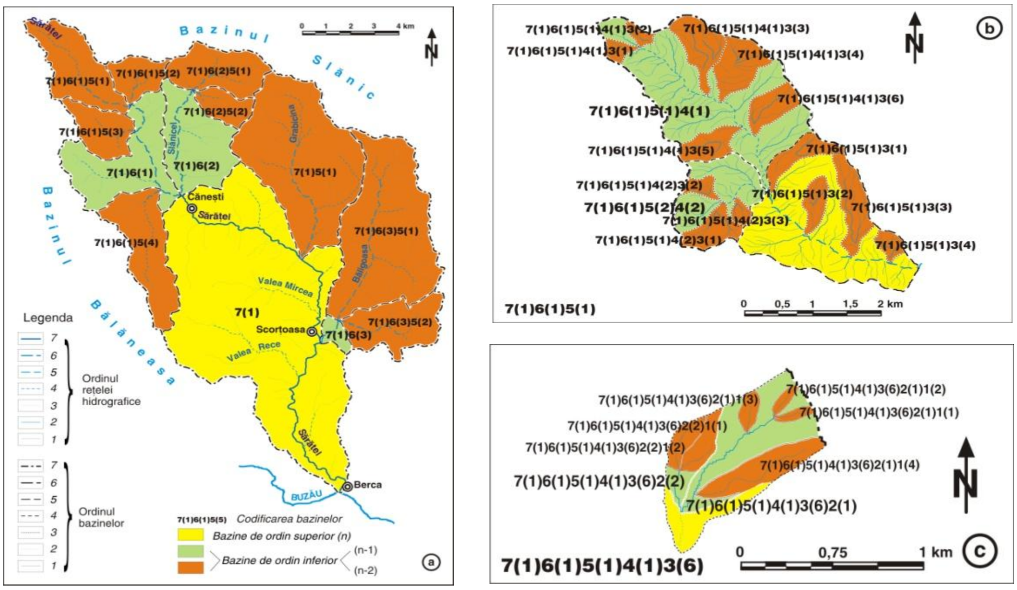

Figure 3 The codification of the sub-basins from the Sărățel hydrographic basin

Conclusions

The proposed coding system is based on the Horton-Strahler classification system which starts from simple to complex, from small to large, from the most recent river segments to the oldest flow channels. By the manner in which it is developed, the systems allows the computing of a wide database, with the morphometric characteristics of the rivers network and of the hydrographic basins of different orders. The code assigned to each basin allows its spatial localisation and the interrogation of the database, a very useful instrument, necessary for the scientific research. The database obtained on magnitude orders can be more easy processed, interpreted and used, taking into account the principle of geographical conditions similarity. The system gives a better characterisation of the physical environment of the hydrographic basins, as a support of the management, monitoring and modelling plans.

Acknowledgements

This work was supported by CNCSIS –UEFISCSU, project number PNII – IDEI 631/2008.

References

Cruceru N., Herişanu Gh., 2010. *The dynamics of the present processes within the Sărățel catchment area*, Geographical Forum, No. 9, Geographical studies and environment protection research, pg. 17-30, ISSN 1583-1523, Craiova;

Furnans J. E., 2001. *Topologic Navigation and the Pfafstetter System*, *Available from*: http://www.crwr.utexas.edu/reports/pdf/2001/rpt01-5.pdf .Horton, R. E., (1945), *Erosional development of streams and their drainage basins: a hydro-physical approach to quantitative morphology*, Geol. Soc. Am., Bull., 56(3, 275 – 370;

Grecu Florina, Zăvoianu, I., 1997. *Morpho-hydrographic basins*, Revista de geomorfologie, nr. 1, Asociația geomorfologilor din România, Bucureşti;

Herişanu Gh., Zăvoianu I., Cruceru N., 2010. *Toolbox for determining the volume of eroded material from the catchment*. Annals of DAAAM for 2010, International DAAAM Symposium "Intelligent Manufacturing & Automation - Focus On Interdisciplinary Solutions" Editor B.[ranko] Katalinic, volume 21, nr.1, pg. 687-688, ISSN 1726-9679, ISBN 978-3-901509-73-5, Vienna, Austria, EU;

Verdin K.L. and Verdin J.P., 2007. *A topological system for delineation and codification of the Earth's river basins.* Journal of Hydrology 218, 1-12., 1999. Voght, J. & Foisneau, S. CCM River and cathchment database, Version 2.0, Analysis Tools;

Zăvoianu I., 1985. *Morphometry of Drainage Basins*, Elsevier, ISBN 0-444-99587-0, Amsterdam;

Zăvoianu I. Herişanu Gh., Cruceru N., 2009. *Classification and codification systems for stream networks and drainage basins,* Annals of DAAAM for 2009 & Proceedings of the 20st International DAAAM Symposium, ISBN 978-3-901509-70-4, ISSN 1726-9679, pp 358, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria p.0715-0717, 1 fig., abstr.;

Zăvoianu I., Herişanu Gh., Cruceru, N. 2009. *Classification Systems for the Hydrographical Network*, Geographical Forum, Geographical studies and environment protection research, Nr. 8, ISBN 1583-1523, Craiova, p. 58-64, 2 fig., rez., Craiova;

Zăvoianu I., Herişanu Gh., Cruceru N., 2010. *Coding the river network and its basins in the Râmnicu Sărat hydrographic system*, Analele Univ. *Spiru Haret*, Seria Geografie, nr. 13, Edit. Fundației *România de Mâine, ,* pg. 61-70, ISSN 1453-8792, Bucureşti;