

River channel dynamics in the contact area between the Romanian Plain and the Curvature Subcarpathians

Florina GRECU¹, Gabriela IOANA-TOROIMAC¹, Paola MOLIN², Francesco DRAMIS²

Abstract. The morphology of river channels results from the genetic and dynamic characteristics imposed by internal and external morphogenetic forcings. We studied reaches of river courses cutting across the contact area between the Romanian Plain (Carpathians foredeep) and the Curvature Subcarpathians, where active faults are located. In this area a wide monocline of tilted foredeep deposits generated a glaxis-like macro-landform at the mountain front that connects the Subcarpathians with the Romanian Plain. The headwaters of studied rivers are located in the Subcarpathians (Cricovul Dulce River) and in the Carpathians (Prahova, Buzău and Milcov rivers). More in detail, we investigated river channels in plan view by morphometric and multi-temporal air-photo analysis to define the general trends of channel evolution. The results of this study indicate a spatial and temporal variability in the intensity of fluvial dynamic processes. The braided courses crossing the Subcarpathians and the piedmont plain have restrained their channels in width, between 1980 and 2005: by 69% on Buzău R. (on 88 km) and 44% on Prahova R. (on 70 km). This evolution is due to the absence of floods just before 2005 and to human factors (i.e. reservoir-dams on Buzău and mining activity on both rivers). Beside these common aspects, the analysis of each river needs to be detailed in order to better understand the responsible factors.

Keywords: river channels, longitudinal profile, channels pattern, braiding pattern, narrowing active channel.

1. Introduction

The morphology of river valleys results from the genetic and dynamic characteristics imposed by the geological factors (tectonics, structure, lithology), as well as by the control variables related to the external morphogenetic environment (Fig. 1), at both regional and local scale.

In cross section, we focused on landforms resulting from alternating erosion and accumulation processes of the river. We took into consideration mainly the modifications of the flow channel, corresponding to flow transportation in normal/mean conditions according to hydromorphological criteria of J.L. Ballais (2011).

The highly complex fluvial morphodynamics, due to the interaction of water as a shaping agent, and the channel morphology, including alluvial deposits, needs to be analysed in plan view, in longitudinal profile and in cross-section (Grecu & Palmentola, 2003), which partially corresponds with 2D and/or 3D analyses (Arnaud-Fassetta & Fort,

2004; Arnaud-Fassetta et al., 2005; Ioana-Toroimac, 2009; Ioana-Toroimac et al., 2010). So, the morphometric features of the channel resulted from different forcings determine the type of channel and its evolution. More in detail, in plan view, we classify channels as straight, meandered, braided, and wandering following Leopold & Wolman (1957), based on the sinuosity and the multiplicity degree of the channel (Brice 1964; Schumm, 1977; Richards 1985; Mac 1986; Ichim et al., 1989; Bravard & Petit, 2002; Grecu & Palmentola, 2003; Ielenicz, 2004; Charlton, 2008; Rădoane et al., 2008, 2013; Malavoi & Bravard, 2010; Rinaldi et al. 2011 and others).

Our study relies on two hypotheses: 1) river channels (inscribed into the flow channel) are the most dynamic component of hydrosystems and 2) they adjust easily to external forcings, both natural and human. Therefore it is necessary, from time to time, to establish the new features of river channels, as a result of changing in external inputs.

2. Study area

We studied the contact area between the Romanian Plain (Foredeep/Foreland unit) and the Curvature Subcarpathians (Orogen unit).

The Romanian Carpathians are an arcuate mountain chain, formed in response to the continental collision between the European Plate and several microplates during the Alpine orogeny (Schmid et al., 1998; Maţenco & Bertotti, 2000 and references therein; Csontos & Vörös, 2004). The main depocentre in the Carpathians foredeep is the Focşani Depression, where subsidence continues up to present time (Tărăpoancă et al., 2003). During the Pliocene–Quaternary, the western flank of the Focşani depocentre was tilted as a consequence of the uplift of the neighbouring Carpathian chain

(Maţenco et al., 2003; Tărăpoancă et al., 2003; Necea et al., 2005; Leever et al., 2006; Maţenco et al., 2007). This tilting generated a wide monocline at the mountain front, connecting the Curvature Subcarpathians with the Romanian Plain (Fielitz & Seghedi, 2005; Necea et al., 2005). So the study area is interesting because it is in between opposite important regional vertical movements: the uplifting chain and subsiding foredeep (about ± 5 millimetres per year; Zugrăvescu et al., 1998) at less than 100 km in distance (Fig. 2). It is also characterized by the outcrop of rock types susceptible to erosion: sand, clay, conglomerate and marls that record the change from a marine to a fluvial-lacustrine environment (Molin et al., 2012 and reference therein).

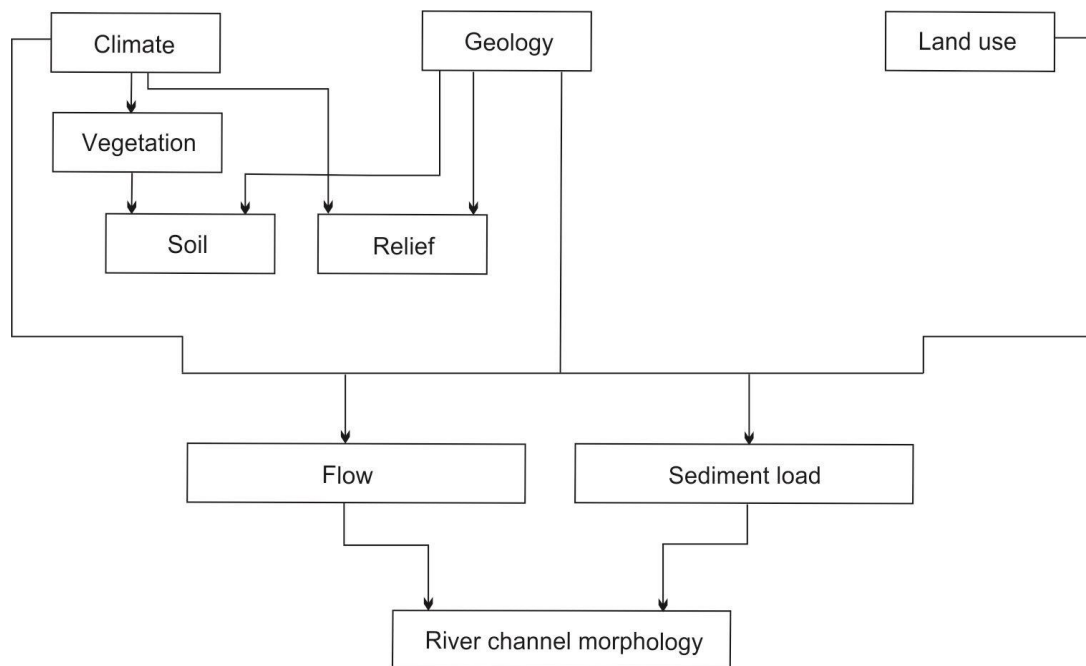


Fig. 1. Control variables related of the external morphogenetic environment (adapted from Knighton, 1984)

From a morphological point of view, the study area includes Curvature Carpathians, Curvature Subcarpathians and Romanian Plain. The contact area between the Subcarpathians and the Romanian Plain is represented by a piedmont belt (glacis-like macro-landform associated with the monocline), traditionally considered a part of the Romanian Plain because of its very gentle slopes (Grecu, 2010). The subsidence of the Romanian Plain coupled with the Carpathian and Subcarpathian uplift induced a regional base level, lowering that

allowed the generation of fluvial terraces and entrenched alluvial fans interacting with the Quaternary climate changes. The element of complexity is also due to local tectonic features, like the anticlines relative to the so-called “Wallachian” phase (Săndulescu, 1988). For example, the anticlines Bucşani and Mărgineni, incised by the Cricovul Dulce and Prahova valleys at the Tinosu point, partially influenced upon the recent evolution and configuration of river network.

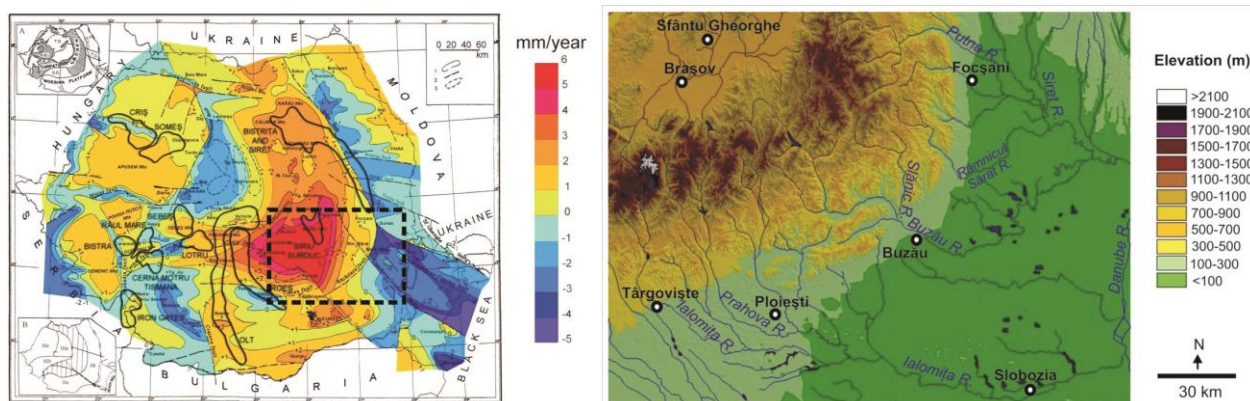


Fig. 2. Study area – Curvature Carpathians: active tectonics (left, within the frame, according to Zugrăvescu et al., 1998) and elevation (right, adapted from SRTM)

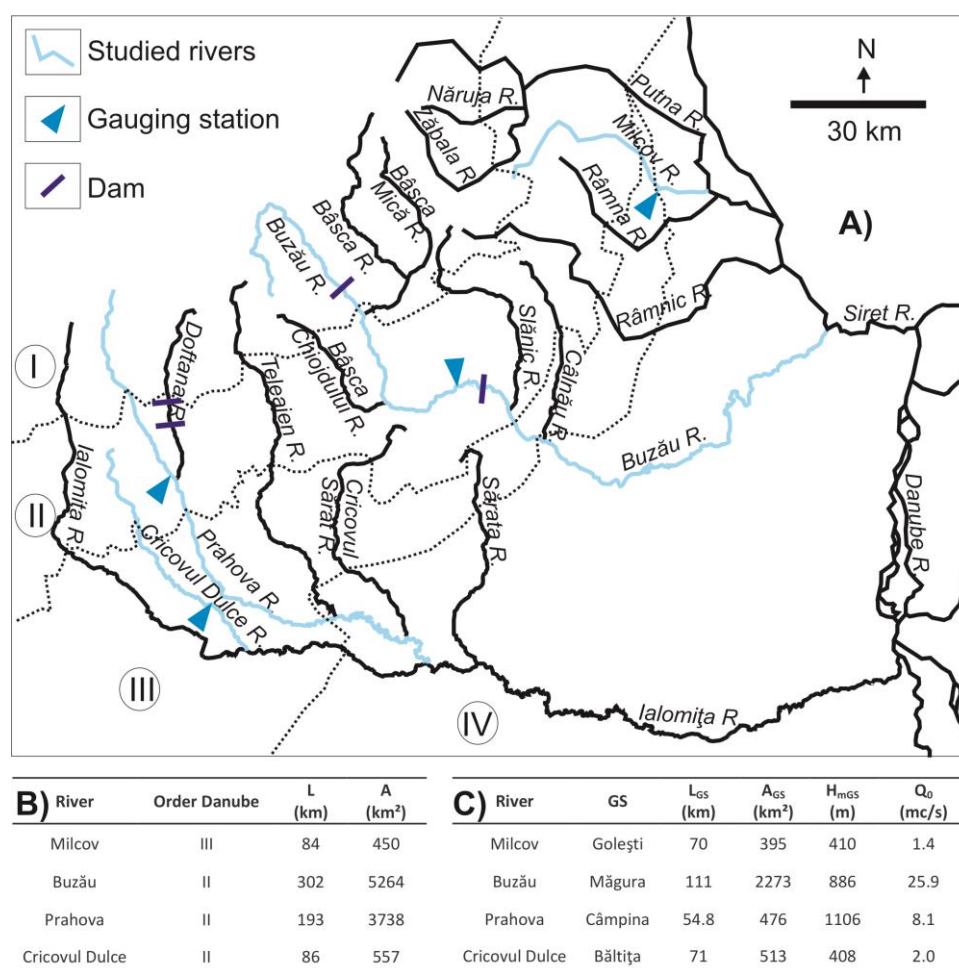


Fig. 3. Studied rivers. A) Geographical position. I: Carpathians; II: Subcarpathians; III: Piedmont plain; IV: Lowland plain. B) Morphometric data of river basins. L: river length; A: catchment area (AQUAPROIECT, 1992). C) Morphometric data of rivers at gauging stations. GS: gauging station; L_{GS}: length; A_{GS}: area; H_{mGS}: mean altitude (source: INMH, 1974); Q₀: mean annual discharge (data from National Institute of Hydrology and Water Management)

These regional features have an influence on rivers crossing the Curvature area. Several rivers of this area have concave and steep longitudinal profiles and they are in a transient state of disequilibrium as a consequence of a more recent emersion of the Curvature Carpathians (Molin et al., 2012). Moreover, other previous studies showed that these rivers have the highest suspended sediments

loads in Romania (up to 25 tonnes per hectare per year) (Mociorniță & Birtu, 1987 cited by Zaharia et al., 2011).

Our study focuses on four rivers flowing down the Carpathians (like Prahova, Buzău and Milcov rivers) or draining just the Subcarpathians (like Cricovul Dulce River). The rivers cross the Carpathian and Subcarpathian (Mesozoic, Paleogene

and Neogene) rocks with different hardness and with great potential to generate landslides. All of them are secondary or thirdly tributaries of the Danube (Fig. 3). The most important (in terms of watershed dimensions and discharge) is Buzău River. Conversely, Milcov River has the smallest drainage basin and discharge.

Besides the natural constraints, the studied rivers are suffering from human recent interventions; some of them will be presented as discussion parts of the paper.

3. Methods and materials

The hydromorphological approach focuses on relief forms of the flow channel generated by sediment-charged water. In the framework of this hydromorphological approach, we determined rivers channel pattern based on two criteria: sinuosity and multiplicity of the branches (Fig. 4). We consider that multiple channel patterns correspond to more than one branch. If the alluvial bars separating the branches lack of vegetation, the channel is considered active. This is the typical example of braiding and wandering patterns.

In order to quantify channel evolution, we compared topographic maps of 1980 (scale 1/25,000) and orthophotos of 2005 (scale 1/5,000). The definition of the active channel on both

topographic maps and orthophotos could be equivocal. On orthophotoplans, we delimited the active channel using colours criteria, but there are several errors related to sediments' humidity, to the hydrological regime phase and, in some cases, to the riparian forest which makes it difficult to digitise its precise limits. On topographic maps, the active channel is represented by a peculiar symbol, but not all channels are represented because of their scale. Therefore, in order to quantify the braiding activity of small rivers, we adopt another parameter: the width of the active channel (according the methods proposed by Peiry, 1988) (Fig. 4). The width is measured along profiles crossing the channel on both topographic maps and orthophotos.

4. Results and discussions

On the basis of these data and methods, we present our results for the four rivers highlighting possible common features.

Buzău River forms a sinuous and unique pattern in the Carpathians, a braiding one in the Subcarpathians and piedmont plain, and a meandering one in the lowlands (Fig. 5A). This is a general picture, because the limits between these patterns are not precise and there are also intermediary types. The braiding pattern corresponds to a slope of 2.7 m/km and it covers 88 km in length.

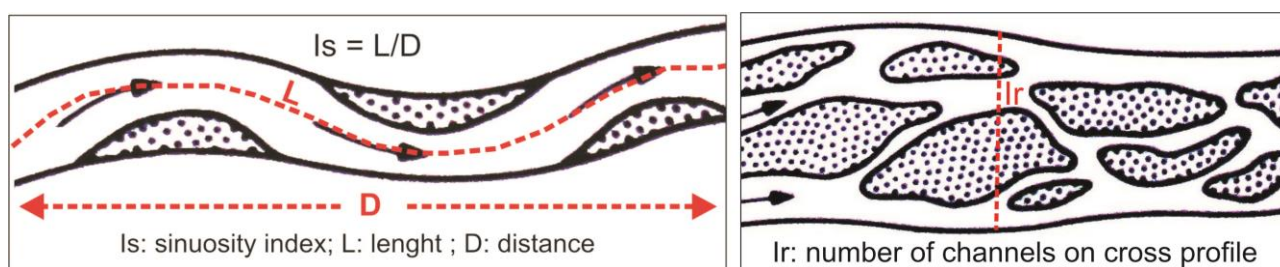


Fig. 4. Methods: sinuosity and braiding indices

Here, we measured its active channel's width on cross profiles located every 500 m on both topographic maps and orthophotos. The results show important variations of the active channel's width (Fig. 5B). For example, it widens at the entrance in the piedmont plain – approximately at the confluence with Slănic River (Fig. 5B). It widens in the vicinity of confluences, which indicate the role of tributaries in bringing yield in the main channel. The width of the active channel started to decrease since 1980, as showed by all the statistic parameters (Fig. 5C). The results relative to the

2005 orthophotos indicate a much smaller variability in channel width. The average width diminished by 69% in 25 years, between 1980 and 2005. In order to visualise this strong decrease, we focused on a 3 km-long reach in Fig. 5D. The inactive channel is presently covered by pasture, which means that the braiding channel could be easily reactivated in the future during extreme floods.

The channel dynamic of Buzău R. appears to be partially influenced by climatic factors acting on short-term and by human-induced factors, mostly dams and mining in the thalweg.

The large width of Buzău river bed in 1980 was probably caused by the floods of the decade 1970-1979 (Grecu et al., 2013). Exceptional floods were recorded in 1975 (when Buzău River reached 2200 m³/s), in 1970, and 1972 (Negru, 2010). The narrowed state of the river channel of 2005 may also be a consequence of the absence of high magnitude floods in the previous years (Grecu et al., 2013); therefore, the channel went back to a state previous to floods.

In the river channel of Buzău R., two dams have been built, one in the upstream course at the boundary between Carpathians and Subcarpathians (Siriu dam) and another one just downstream of the boundary between Subcarpathians and the plain (Cândești dam). Siriu dam is located between the massifs of Siriu and Podu Calului. Its construction began in 1982, and its influence in the river channel dynamics being felt since 1985 (Minea, 2011). The Cândești dam, built up in 1988 and much smaller than Siriu dam, plays also a role in flood control. The position of dams is particularly important as they control river discharge and yield; for example, the maximum water volume that can pass across the Siriu dam is about 3000 m³/s (Negru, 2010). Since the construction of the dams, the maximum discharge was about 925 m³/s (in 2005), thus much smaller than the previous one, diminishing the risk.

Downstream Cândești dam, the mining activity intensified since the '80s (figures 6A and B). More in detail, at the contact between Subcarpathians and Romanian Plain, in the Buzău county, there are more than 50 gravel pits. The exploited volumes differ a lot from one gravel pit to another. For example, the big gravel pit in Săpoca (near the confluence of Slănic into Buzău R.), where 7 commercial societies are involved, only one of them extracts yearly between 40000 – 50000 m³ (according to data from Environment Protection Agency of Buzău County). Gravel mining could cause an increase in both upstream and downstream incision with a consequent transient reduction in channel width.

Another cause of the narrowing may be related to the construction of a canal in the active channel, for water supply of Buzău city, located a few kilometres downstream.

In the case of Prahova River, the scenario is similar to Buzău R. one. The braiding pattern, 70 km long, corresponds to the Subcarpathians and piedmont plain (Fig. 7A) (Ioana-Toroimac, 2009). The active channel's width has been measured every 250 m along cross profiles. Numerous width variations are present. At the entrance in the piedmont plain, downstream the confluence with Doftana River (Fig. 7B), the valley bottom is bordered by terraces few tens of meters high. Its maximum width is located several kilometres downstream, where the terraces disappear. The mean width of Prahova R. diminished by 44% between 1980 and 2005 (Fig. 7C). In order to visualize this evolution, we focused on a smaller section; the abandoned active channel is used as a pasture and may be overflowed (Fig. 7D). This trend of evolution is confirmed by other studies (Ioana-Toroimac et al., 2010; Armaș et al., 2013).

Milcov River has only its springs in the Carpathians, but it drains mostly the Subcarpathians, that are the most important source of water discharge and sediments (Săcrieru, 2009). It forms braiding channels in the Subcarpathians and in the piedmont plain (Fig. 8A) on a reach of 44 km-long and on a slope of 7.7 m/km. Many variations in active channel's width are present all along the river course. For example, it widens in the piedmont plain, whereas natural constraints in the Subcarpathians do not allow active channel widening (Fig. 8B). For a more detailed analysis of the Milcov R. evolution, we focused on this reach of 6 km-long; its mean width diminished by 43% between 1980 and 2005 (Fig. 8D).

Similarly to all the rivers, Cricovul Dulce River forms braiding and wandering channels in the Subcarpathians and in the piedmont plain (Săndulescu, 2011) (Fig. 9A). But this reach has features different with respect to the other studied rivers. It is characterized by alternating braiding reaches and unique reaches (Fig. 9B). Cricovul Dulce River suffers from the same process of narrowing, but it is apparently less important. The average width diminished by 18% (figures 9C and D).

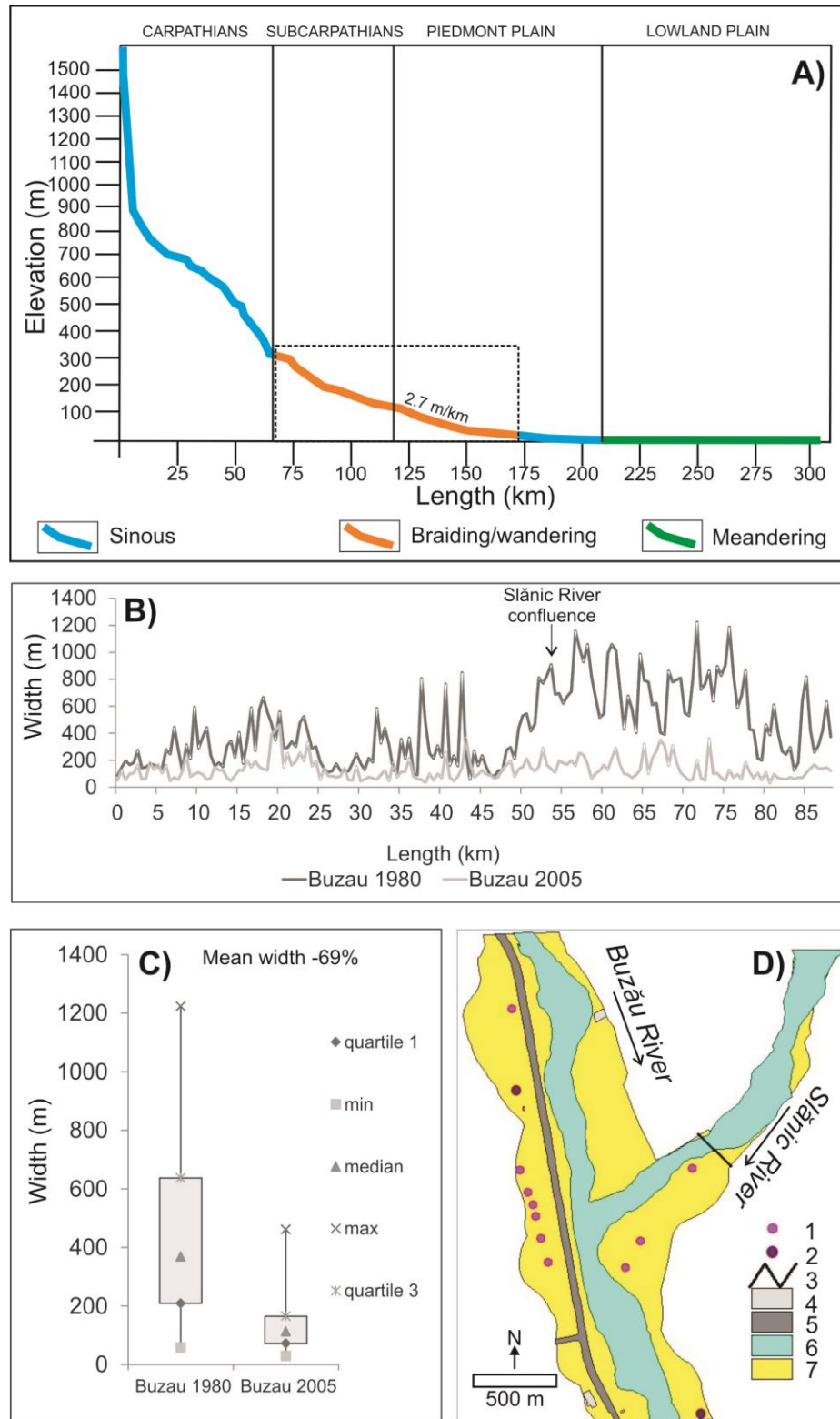


Fig. 5. Buzău River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel, measured every 500 m, in 1980 and 2005. C) Active channel narrowing between 1980 and 2005. D) Active channel dynamics at Buzău – Slănic confluence. 1: ancient/abandoned borrow pit; 2: borrow pit; 3: bridge; 4: built-up area; 5: artificial channel; 6: active channel 2005; 7: active channel 1980

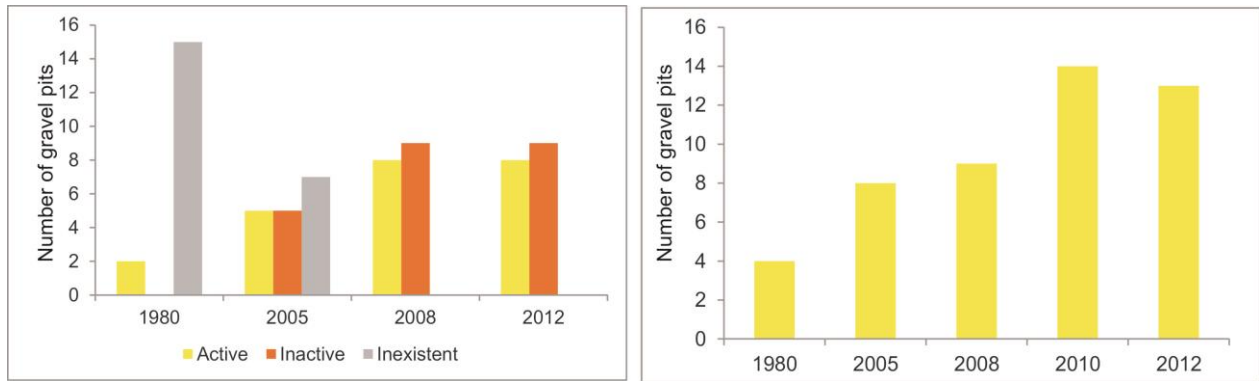


Fig. 6. Mining activity on Middle Buzău River. A) Between km 52 and 68 (according to figure 5B): status compared to the one of 2012. B) Between km 68 and 88 (according to figure 5B): active mining (analysis based on topographic maps of 1980 and several orthophotos of ANCPI, 2014)

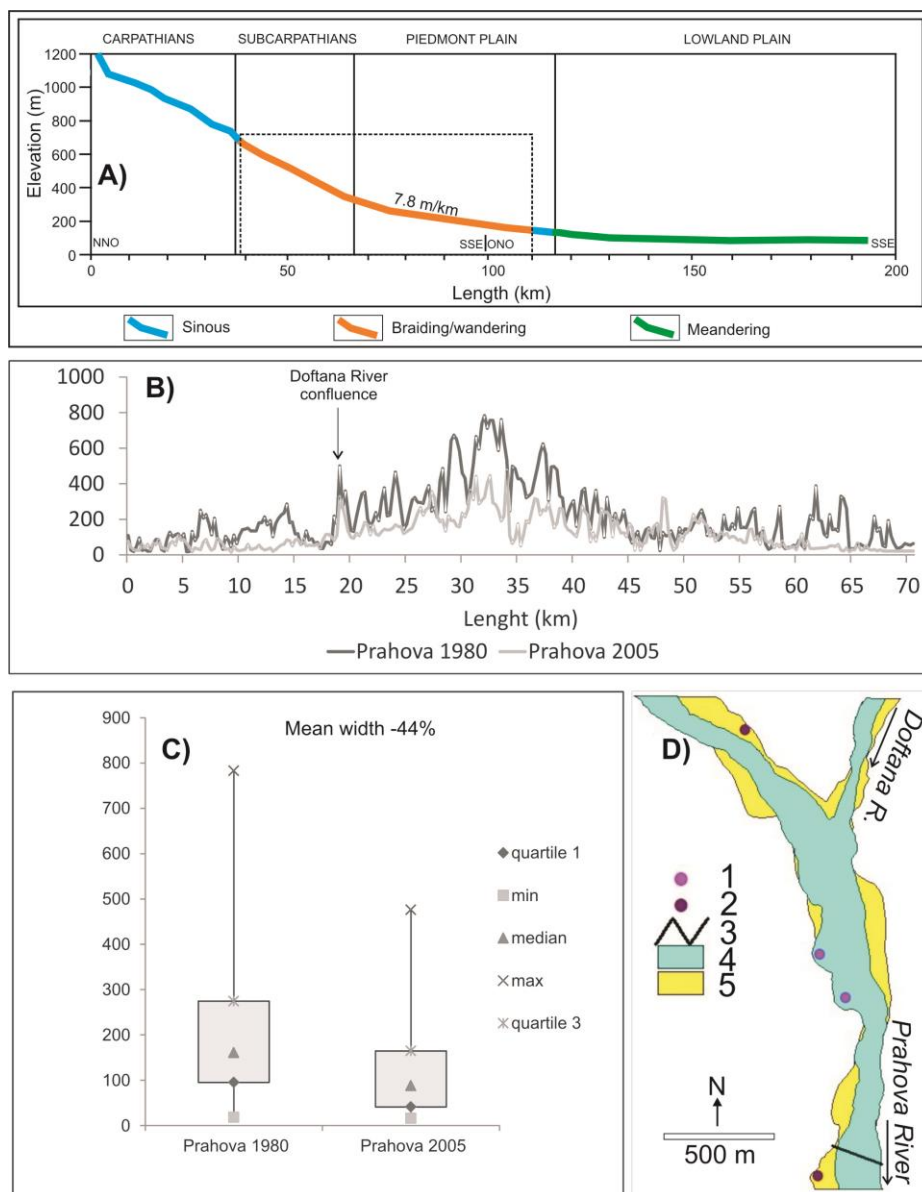


Fig. 7. Prahova River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel, measured every 250 m, in 1980 and 2005. C) Active channel narrowing between 1980 and 2005. D) Active channel dynamics at Prahova – Dofana confluence. 1: ancient/abandoned borrow pit; 2: borrow pit; 3: bridge; 4: active channel 2005; 5: active channel 1980

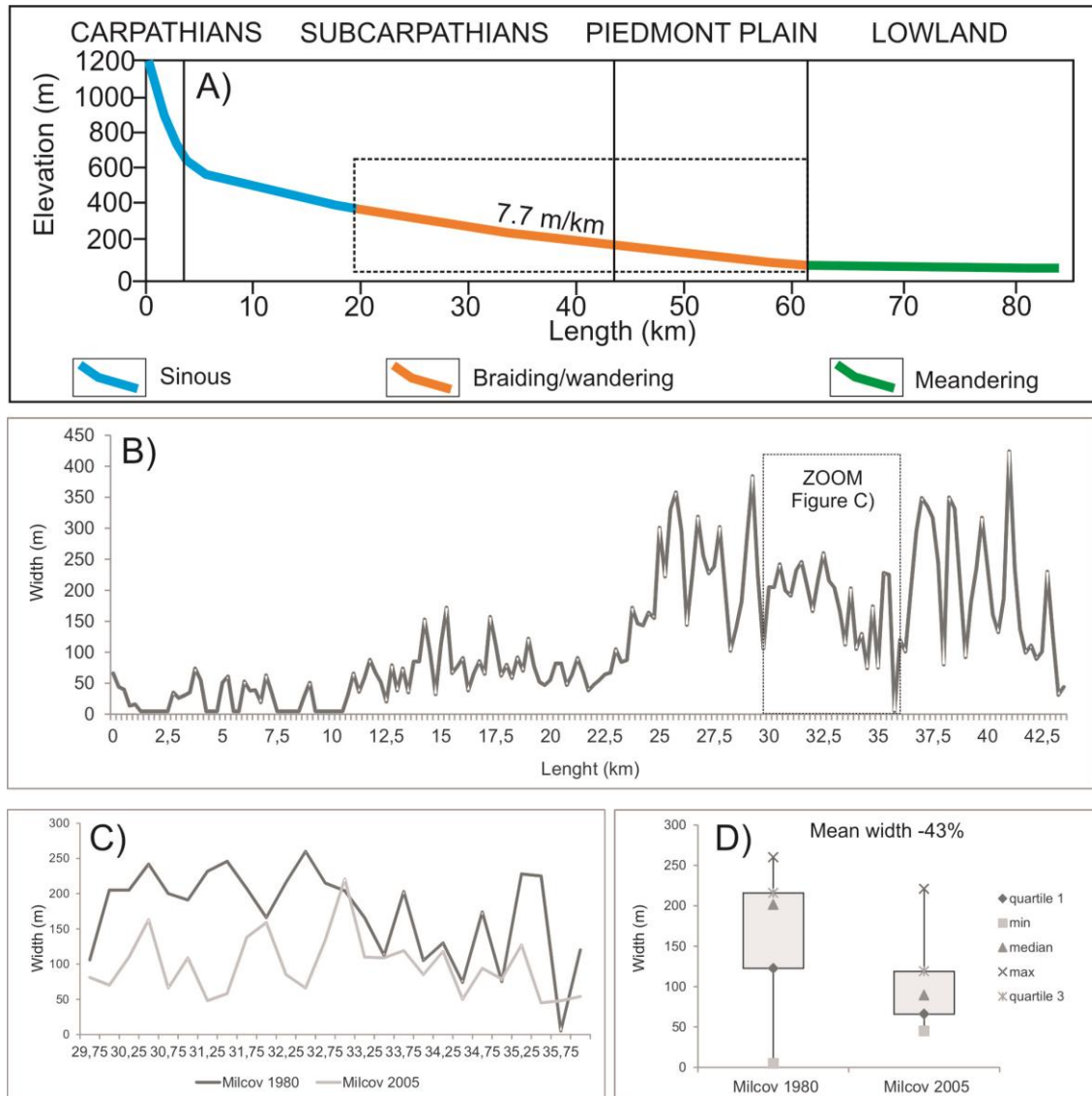


Fig. 8. Milcov River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel in 1980, measured every 250 m. C) Width variations of a river reach between 1980 and 2005. D) Active channel narrowing of the river reach from figure C between 1980 and 2005

6. Conclusions

The rivers crossing the study area form a unique, sinuous channel in the Carpathians and just locally in the Subcarpathians. They form braiding and wandering channels in the Subcarpathians and in the piedmont unit of the Romanian Plain; their origin, length and width depend on the water and sediments resources of each watershed. Downstream, crossing the lowland units of the Romanian Plain, they form meandering channels. In conclusion, channel pattern is related to morphological units and the majority of the rivers respect these patterns.

All the investigated braided rivers adjust to external changes and suffer a narrowing process of different intensities. A fluvial metamorphosis does

not occur, but this process is possible in the near future as the narrowing continues at the present rate. It is difficult to establish the role of each external factor in this evolution, because their actions are synchronous and simultaneous. We notice that gravel mining is an important activity in Romania and it probably plays an important role in channel's evolution. Beside these common aspects, the analysis of each river needs to be detailed, because each river is a unique example. These are only a few examples, which show that it is necessary to conduct the same study on all the major braided rivers.

This study is important because it fills a lack of studies on braiding activity of Romanian rivers and it highlights the general process of narrowing of

channels in the Subcarpathians and piedmont sectors of their courses. Moreover, it could contribute to the geoconservation of braided rivers which the narrowing process, almost caused by human activity, is progressively destroying.

This paper was presented at the 16th Joint Geomorphological Meeting on Morphoevolution in Tectonically Active Belts, Rome and Central Apennine Mountains, Italy, 1-5 July 2012.

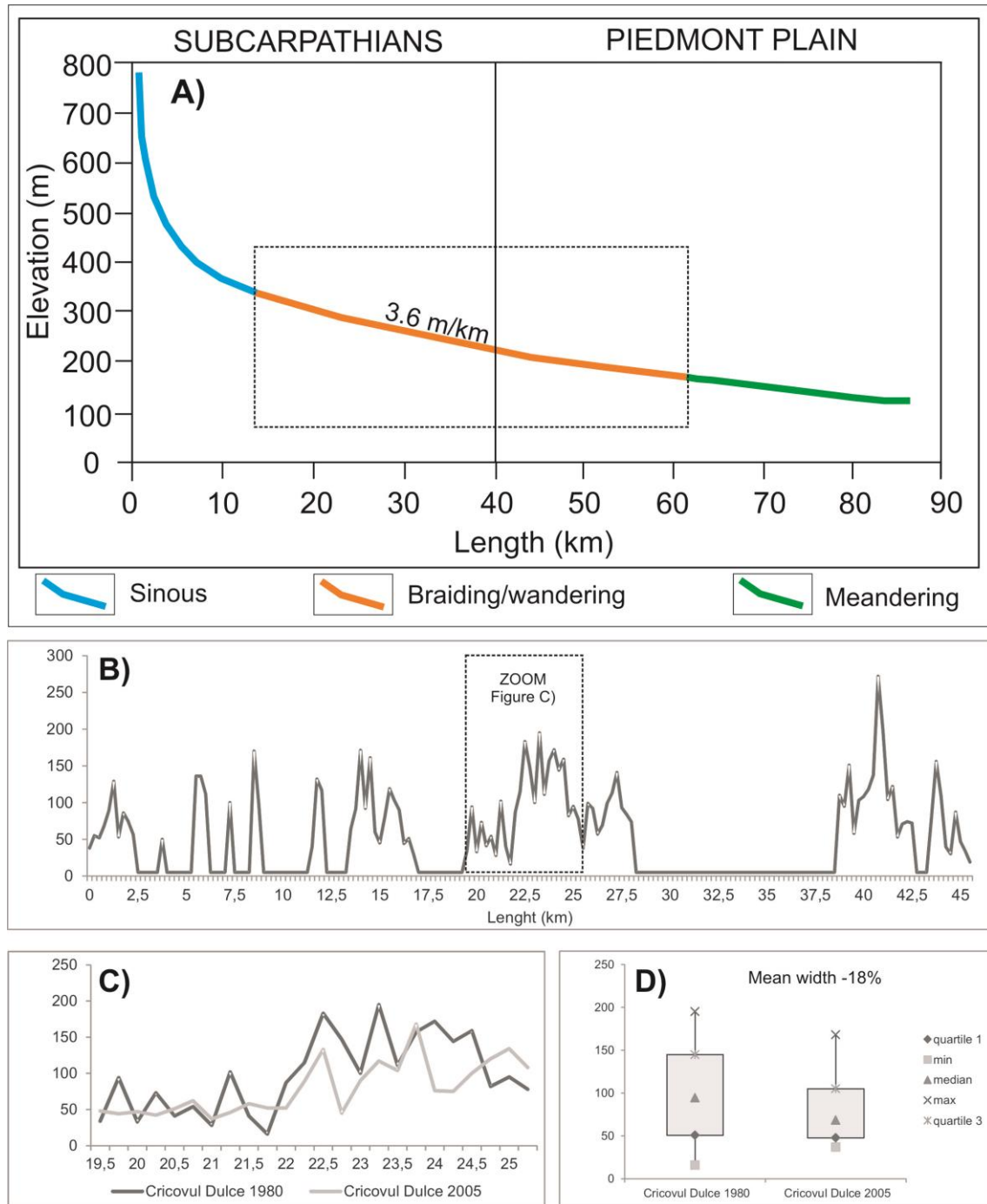


Fig. 9. Cricovul Dulce River dynamics. A) Longitudinal profile with channel patterns. B) Width of the braided active channel in 1980, measured every 250 m. C) Width variations between 1980 and 2005 on a river reach. D) Active channel narrowing of the river reach between 1980 and 2005.

REFERENCES

- AQUAPROIECT, (1992), *Atlasul Cadastrului Apelor din România*, Ministerul Mediului, Bucharest, 694 p.
- ANCPI, (2014), *Geoportal*, <http://geoportal.ancpi.ro/geoportal/viewer/index.html>, consulted on 10/01/2014
- ARMAŞ, I., NISTORAN, D.E., OSACI-COSTACHE, G., BRAŞOVEANU, L., (2013), "Morpho-dynamic evolution patterns of Sub-carpathian Prahova River (Romania)", *Catena*, **100**: 83-99.
- ARNAUD-FASSETTA, G., FORT, M., (2004), "La part respective des facteurs hydroclimatiques et anthropiques dans l'évolution récente (1956-2000) de la bande active du Haut Guil, Queyras, Alpes françaises du Sud", *Méditerranée*, **1-2** : 143-156.
- ARNAUD-FASSETTA, G., COSSART, E., FORT, M., (2005), "Hydro-géomorphologic hazards an impact of man-made structures during the catastrophic flood of June 2000 in the Upper Guil catchment (Queyras, Southern French Alps)", *Geomorphology*, **66**: 41-67.
- BALLAIS J.L., CHAVE S., DUPONT N., MASSON E., PENVEN M.J., (2011), *La méthode hydrogéomorphologique de détermination des zones inondables*, Physio-géo, Géographie Physique et Environnement, Collection « Ouvrages », 172 p.
- BRAVARD, J.P., PETIT, F., (2002), *Les cours d'eau. Dynamique du système fluvial*, Editions Armand Colin, Paris, 222 p.
- BRICE J.C., (1964), *Channel patterns and terraces of the Loup River in Nebraska*, United States Geological Society, Paper 422 D, 41 p.
- CHARLTON, R., (2008), *Fundamentals of fluvial geomorphology*, Routledge, London-New York, 234 p.
- CSONTOS, L., VÖRÖS, A., (2004), "Mesozoic plate tectonic reconstruction of the Carpathian region. Palaeogeography, Palaeoclimatology", *Palaeoecology*, **210**: 1-56.
- FIELITZ, W., SEGHEDI, I., (2005), "Late Miocene–Quaternary volcanism, tectonics and drainage system evolution in the East Carpathians, Romania", *Tectonophysics*, **410**: 111-136.
- GRECU, F., PALMENTOLA, G. (2003), *Geomorfologie dinamică*, Editura Tehnică, Bucharest, 392 p.
- GRECU, F., (2010), *Geografia câmpiilor României*, Editura Universităţii din Bucureşti, Bucureşti, 258 p.
- GRECU, F., IOANA-TOROIMAC, G., DOBRE, R., ZAHARIA, L., (2013), "River channel recent dynamics in relation to floods in the Curvature Carpathians", Poster presentation within 8th Conference of International Association of Geomorphologists, 27-31.08, Paris.
- ICHIM, I., BĂTUCĂ, D., RĂDOANE, M., DUMA, D., (1989), *Morfologia şi dinamica albiilor de râu*. Editura Tehnică, Bucharest, 408 p.
- IELENICZ, M., (2004), *Geomorfologie*, Editura Universitară, Bucharest, 344 p.
- IOANA-TOROIMAC, G., (2009), *La dynamique hydrogeomorphologique de la rivière Prahova (Roumanie)*, PhD thesis in Geography, University of Lille 1 and University of Bucharest, 341 p.
- IOANA-TOROIMAC, G., DOBRE, R., GRECU, F., ZAHARIA, L. (2010), "Evolution 2D de la bande active de la Haute Prahova (Roumanie) durant les 150 dernières années", *Géomorphologie : relief, processus, environnement*, **3** : 275-286.
- I.N.M.H., (1974), *Anuarul hidrologic*, Institutul Naţional de Meteorologie şi Hidrologie, Bucureşti, 1356 p.
- KNIGHTON, D., (1984), *Fluvial forms and processes*, Arnold, London, 218 p.
- LEEVE, K.A., MAŢENCO, L., BERTOTTI, G., CLOETINGH, S., DRIJKONINGEN, G.G., (2006), "Late orogenic vertical movements in the Carpathian Bend Zone — seismic constraints on the transition zone from orogen to foredeep", *Basin Research*, **18**, 521-545.
- LEOPOLD, L.B., WOLMAN, M.G., (1957), *River channel patterns: braided, meandering and straight*. Rap. tech. US Geological Survey, US government printing office, Washington, 76 p.
- MAC, I., (1986), *Elemente de geomorfologie dinamică*, Editura Academiei, Bucharest, 215 p.
- MALAVOI, J., R., BRAVARD, J.P., (2010), *Eléments d'hydromorphologie fluviale*, Onema, 224 p.
- MAŢENCO, L., BERTOTTI, G., (2000), "Tertiary tectonic evolution of the external East Carpathians (Romania)", *Tectonophysics*, **316**: 255-286.
- MAŢENCO, L., BERTOTTI, G., CLOETINGH, S., DINU, C., (2003), "Subsidence analysis and tectonic evolution of the external Carpathian–Moesian Platform region during Neogene times", *Sedimentary Geology*, **156**: 71-94.
- MAŢENCO, L., BERTOTTI, G., LEEVE, K., CLOETINGH, S., SCHMID, S., TĂRĂPOANCĂ, M., DINU, C., (2007), "Large-scale deformation in a locked collisional boundary: interplay between subsidence and uplift, intraplate stress, and inherited lithospheric structure in the late stage of the SE Carpathians evolution", *Tectonics*, **26**: TC4011.
- MINEA, S., (2011), *Râurile din bazinul Buzău. Consideraţii hidrografice şi hidrologice*, Editura Alpha MDN, Buzău, 306 p.
- MOLIN, P., FUBELLI, G., NOCENTINI, M., SPERINI, S., IGNAT, P., GRECU, F., DRAMIS, F., (2012), "Interaction of mantle dynamics, crustal tectonics and surface processes in the topography of the Romanian Carpathians: a geomorphological approach", *Global and Planetary Change*, **90-91**: 58-72.
- NECEA, D., FIELITZ, W., MAŢENCO, L., (2005), "Late Pliocene–Quaternary tectonics in the frontal part of the SE Carpathians: insights from tectonic geomorphology", *Tectonophysics*, **410**: 137-156.
- NEGRU, O., (2010), "Managementul inundaţiilor în bazinul hidrografic Buzău, *Proceedings of the Conference Water resources from Romania. Vulnerability to the pressure of man's activities*, 184-188.
- PEIRY, J.L., (1988), *Approche géographique de la dynamique spatio-temporelle des sédiments d'un cours d'eau intra-montagnard : l'exemple de la plaine alluviale de l'Arve (Haute-Savoie)*. PhD thesis in Geography, University of Lyon 3, 376 p.
- RĂDOANE, M., RĂDOANE, N., CRISTEA, I., OPREA-GANCEVICI, D., (2008), "Evaluarea modificărilor contemporane ale albiei râului Prut pe graniţa românească", *Revista de Geomorfologie*, **10**: 57-73.
- RĂDOANE, M., PERŞOIU, I., CRISTEA, I., CHIRILOAEI F., (2013), "River channel planform changes based on successive cartographic data. A methodological approach", *Revista de Geomorfologie*, **15**: 69-88.
- RICHARDS, K., (1985), *Rivers. Form and Processes in Alluvial Channel* – Methuen, London and New York, 360 p.
- RINALDI, M., SURIAN, N., COMITI, F., BUSSETTINI, M., (2011), *Guidebook for the evaluation of stream morphological conditions by the Morphological Quality Index (IQM)*, version 1, ISPRA-Istituto Superiore per la Protezione e la Ricerca Ambientale, Roma, 84 p.

- SĂCRIERU, R., (2009), *Bazinul morfohidrografic Milcov, Studiu geomorfologic*, PhD thesis in Geography, University of Bucharest.
- SĂNDULESCU, M., (1988), "Cenozoic tectonic history of the Carpathians", In: ROYDEN, L., HORVÁT, F. (Eds.), *The Pannonian Basin*, American Association of Petroleum Geologists, *Memoir*, **45**: 17–26.
- SĂNDULESCU, V., (2011), *Bazinul hidrografic Cricovul Dulce. Studiu geomorfologic*, PhD thesis in Geography, University of Bucharest.
- SCHMID, S.M., BERZA, T., DIACONESCU, V., FROITZHEIM, N., FUEGENSCHUH, B., (1998), "Orogenparallel extension in the South Carpathians during the Paleogene", *Tectonophysics*, **297**: 209–228.
- SCHUMM, S.A., (1977), *The fluvial system*, John Wiley & Sons Ltd, London, 388 p.
- TĂRĂPOANCĂ, M., BERTOTTI, G., MAȚENCO, L., DINU, C., CLOETINGH, S., (2003), "Architecture of the Focșani depression: a 13 km deep basin in the Carpathians Bend zone (Romania)", *Tectonics*, **22**: 1074.
- ZAHARIA, L., GRECU, F., IOANA-TOROIMAC, G., NECULAU, G., (2011), "Sediment transport and river channel dynamics in Romania – variability and control factors", in MANNING, A.J., (ed.), *Sediment transport in aquatic environments*, INTECH, Rijeka, 293–316.
- ZUGRĂVESCU, D., POLONIC, G., HOROMNEA, M., DRAGOMIR, V., (1998), "Recent vertical crustal movements on the romanian territory, major tectonic compartiments and their relative dynamics", *Revue roumaine de géophysique*, **42**: 3–14.

¹ **University of Bucharest, Faculty of Geography
Department of Geomorphology-Pedology and Geomatics,
N. Bălcescu Blv, 1, 010074, Sector 1, Bucharest, Romania.**

florinagrecu@yahoo.com, gabriela.toroimac@geo.unibuc.ro

² **Roma Tre University, Department of Geological Sciences**
paola.molin@uniroma3.it, dramis@uniroma3.it