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AREAS WITH FLOOD POTENTIAL RISK IN THE LOWER UZ CATCHEMENT (ROMANIA). PROTECTION AND MITIGATION MEASUREMENTS

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Key words: AHP (*Analytic Hierarchy Process)*, GIS, Floods, Weighting, Hydrological risk

Abstract: The identification of areas with flood potential risk is important concerning the rational management of emergencies in case of floods. The most significant floods in the history of Romania occurred in the catchment basin of Siret (Uz River being an indirect tributary) and Prut. The analysis focused on the identification of flood potential risk index. The study involves the analysis of natural and anthropogenic physical and geographic factors: lithology, land declivity, soil texture, profile curvature and land use. The weighting of each analyzed factor for the contribution to floods was obtained using the AHP extension of the ArcGIS software. This methodology was applied for the lower Uz river basin, situated downstream from Lake Poiana Uzului. The catchment basin of Uz was affected by major floods in the summer of 2005, while the Uz River recorded a maximum historic discharge of 132 m^3/s, at the precipitation station of Darmanesti, situated upstream from the Poiana Uzului reservoir. The consequences of the historic high water were serious. Extended surfaces within the major riverbed were flooded, numerous houses were partially damaged and some destroyed. The study highlights that the highest values of flooding index range between 3.96 and 4.71 and that they affect 14% of the entire surface of the studied area.

Introduction

The current modifications produced in the climatic (thermal and pluviometrical) and hydrologic climate in Romania and in Eastern Europe represented the main argument of numerous studies within the catchment basins of

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the Carpathian Mountains (Birsan et al., 2014; Chirila et al. 2008; Cojoc et al., 2015; Hapciuc et al., 2016; Mihu-Pintilie and Romanescu, 2011; Mihu-Pintilie et al., 2014; Reti et al., 2014; Romanescu and Stoleriu, 2013a; Romanescu et al., 2011, 2012; Serban et al., 2016; Stancalie et al., 2012; Tirnovan et al., 2014a,b).

The analysis of hydrologic risk phenomena represents a real concern for scientists within all countries of the world because such phenomena have occurred more frequently in the past decades (Barbulescu and Maftei, 2015; Costache et al., 2017; Hapciuc et al., 2015; Romanescu, 2003, 2005, 2006; Romanescu and Nistor, 2011; Romanescu et al., 2011; Tirnovan et al., 2014a,b). Floods represent the most dangerous risk phenomenon, entailing the most serious consequences at an economic and social level (Čech and Čech, 2016; Corduneanu et al., 2016; Diaconu et al., 2017; Komínková et al., 2015; Langovic and Dedjanski, 2017; Li et al., 2015, 2017; Lóczy et al., 2014; Mierla et al., 2015; Mu and Mu, 2013; Raška, 2015; Romanescu and Stoleriu, 2013a,b, 2014, 2017;Romanescu et al., 2011, 2012, 2015, 2016; Solín et al., 2011; Su et al., 2017; Yang et al., 2014).

The catchment basin of Uz has been inflicted by catastrophic floods in the last decade of the 21st century, which were included in the floods affecting the entire area of the Eastern Carpathians: 2001, 2002, 2004, 2005, 2006, 2007, 2008, 2010 and 2011. The highest discharges were recorded in the summer of 2005, while the Siret River registered the Romanian record of historic discharge: 4650 m^3/s (Miftode and Romanescu, 2016; Romanescu et al., 2011) (Fig. 1).

The amplification of the floodable areas within the catchment basin of Uz was due to the enlargement of major riverbeds, which reduced the slopes after the aggradation of the riverbed. If the superficial runoff potential is learnt, it is possible to mitigate the severity of rapid runoff phenomena. Using the GIS techniques, we may analyze the way physical-geographic and economic factors may influence the emergence of superficial runoff. Superficial runoffs present a high potential in case of lands consisting of pastures, deforested zones and built areas. This study was based on the spatial modelling of the area, thus determining a flood potential index. Based on this index, we may quantify and perform the following: flooding risk; areas with risk potential; measures for mitigating damage; protection of the population, etc.

Study area

The catchment basin of Uz is situated in the eastern part of Romania and it is part of the Eastern Carpathians. It covers a surface of 475 km^2 and it ranges between the meridians of 26°00’16” - 26°30’56” E longitude and the parallels of 46°08’44” - 46°23’27” N latitude (Fig. 1). It comprises two lakes: Balatau, a natural dam lake, situated on the Izvorul Negru River; Poiana Uzului, a man-made dam lake, situated on the stream of the Uz river, downstream from the locality of Cremenea and upstream from the locality of Darmanesti (Miftode et al., 2016).

The studied area is situated downstream from Lake Poiana Uzului and it covers 76 km^2. The Uz River is a right-side tributary of Trotus River and it springs from the Ciucului Mountains, from an altitude of 1175.33 m. It crosses the catchment basin on a length of 46 km and it meets the Trotus River in the locality of Darmanesti, at an altitude of 320.43 m (Miftode et al., 2016; Siret Water Basin Administration, 2015).

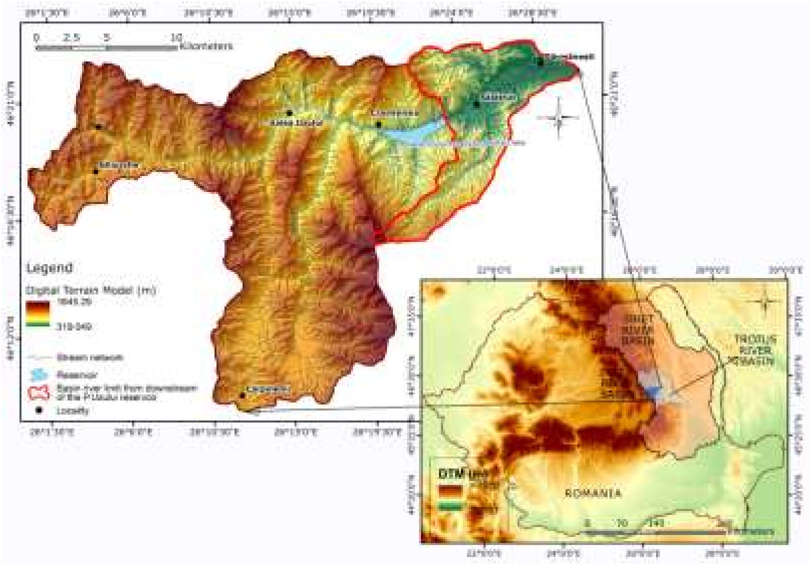

Fig. 1 - Geographic location of the Uz catchment basin

Materials and methods

The hydrologic data were provided by the Siret Water Basin Administration and by the Poiana Uzului Hydroelectric Power Plant (Siret Water Basin Administration, 2015). Some of the historical data were found in the Romanian scientific literature (Birsan et al., 2014; Chendes et al., 2015; Cojoc et al., 2015; Romanescu, 2013; Romanescu et al., 2014). The slope rasters and profile curvature were obtained by processing the digital elevation model (scale of 1:5000), using the ArcGIS software v.10.2.2. The cartographic basis was represented by orthophotoplans (scale of 1:5000) and topographic plans and maps (1:1000 and 1:5000 scale), etc. The software used for processing were as follows: ArcGIS v.10.2.2, AHP extension (ArcGIS).

For the studied area, the flood potential index adapted after the index proposed by Smith for the Colorado River basin was analyzed. Subsequently, it has been improved and calculated for most important rivers (Smith, 2003). It was obtained by analyzing and integrating in GIS five physical-geographic and economic-geographic factors that contribute to the accumulation of water on the soil

Tab. 1 - Classification of natural and anthropogenic physical-geographic factors in the lower Uz river basin (FPI)

Factor\ Estimation score	1	2	3	4	5
Lithology 7.81%	Gravels, sands; Sands, gravels, loess deposits	Diluvium-proluvium deposits	Sand stones, tuffaceous sandstones, andesites, cinerite; Conglomerates, sandstones, marls and charcoal	Shale limestone flysch (Horgazu); Sandstone flysch (Tarcau), sandstone flysch with shale interleaves, shale flysch with stripes; Shale flysch with shale interleaves, conglomerates with green shales elements; Sandstone shale flysch, shale flysch; Black shale flysch (Audia)	-
Slope (°) 41.81%	>25	15-25	7-15	3-7	0-3
Soil texture 6.46%	Clay-sandy	Clay; Varying texture	Clay…clay-loamy; Water	-	-
Profile curvature 27.81%	-	-	0.9 – 15.4	0 – 0.09	-25.9 – 0
Land use 16.04%	Broad-leaved forest; Coniferous forest; Mixed forest	Transitional woodland-shrub	Complex cultivation patterns; Land principally occupied by agriculture with significant areas of natural vegetation	Pastures	Continuous/ Discontinuous urban fabric; Green urban areas; Industrial or commercial units; Road and rail networks and associated land; Water bodies and courses

(lithology, slope, soil texture, profile curvature and land use). Lithology and soil texture were obtained by vectoring the Geological Map of Romania, with a scale of 1:200000 (reprised from the site geo-spatial.org), as well as the Map of Romanian Soils, with a scale of 1:200000. Land use was extracted, in a vector format, from Corine Land Cover 2012 (land.copernicus.eu/pan-european/corine-land-cover). The vectors were converted into raster through the ArcGIS v.10.2.2 software. The five factors were reclassified and they received estimation scores by their influence upon the occurrence of floods (Table 1).

In order to obtain the weighting of each factor (the extent to which they influence the occurrence of floods), the AHP extension (*Analytic Hierarchy Process*) of the software was used. The AHP method was designed by Saaty in 1980 (Saaty, 1980) and it is a multi-criteria analysis method based on comparisons between pairs of factors which influence, in this study, the superficial water runoff.

Results and discussions

Upon finding out the flood potential of the land, it becomes possible to mitigate the severity of this phenomenon. Using the GIS techniques, the way geographic, natural and anthropogenic factors may influence water accumulation on land can be analyzed. The studied area also includes the localities situated in the basin area. Flooding risk presents a high potential in case of lands with anthropogenic intervention (surfaces comprising pastures, deforested areas, built areas, etc).

In order to conduct the study, the spatial modelling of the area was elaborated, thus determining a flood potential index. Five factors influencing the runoff process were analyzed, namely lithology, slope, soil texture, profile curvature and land use (Fig. 2).

Lithology (7.81%) influences the emergence of the floods through the hardness degree of rocks. The highest weighting (42%) pertains to the one of class 4 (flysch). The other classes consist of sands, gravels, deposits, sandstones, marls and shale (Fig. 2A).

Slope (41.88%) is an essential component, which contributes to the rapid response of the basin and which influences greatly the rapid flood potential. The lower Uz river basin as a depression area generally comprises slopes under 20°. The highest values are found on the high slopes, especially in the areas from where the main tributaries of the Uz River spring (Fig. 2B).

Soil (6.46%) – as a physical-geographic factor – has a direct influence upon the production of floods, (through texture, permeability degree and structure). The finer the soil texture and the lower the water permeability, the faster the water accumulation on the soil surface. The highest weighting pertains to soils with

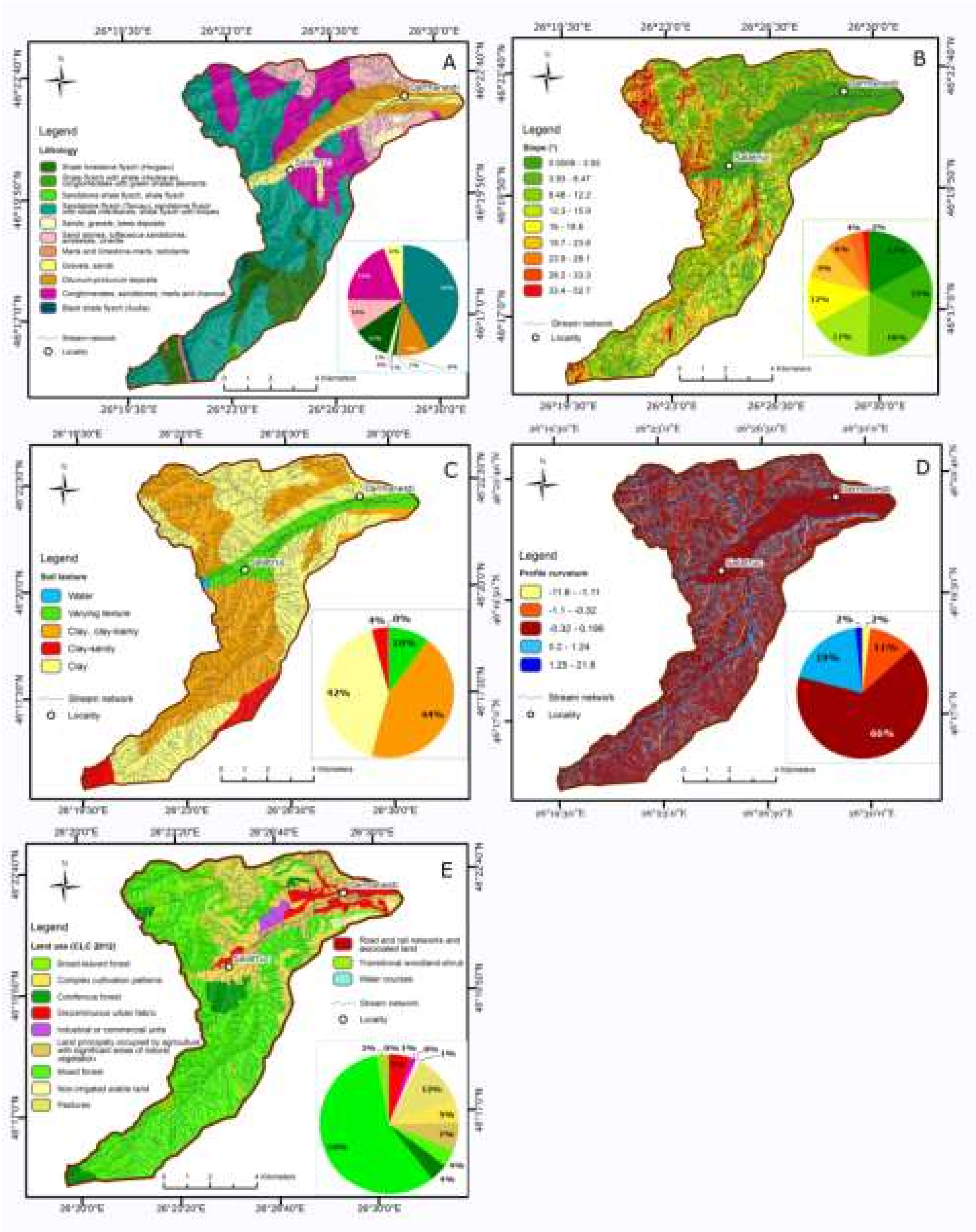

Fig. 2 - Factors that contribute to the FFPI index: A-lithology; B-slope; C-soil texture; D-profile curvature; E-land use

loamy, clay-loamy texture (44%) and clay texture (42%). Along the Uz River valley, the soil has a varied texture (Fig. 2C).

The negative values (convex slopes) of the profile curvature (27.81%) indicate the areas where water may accumulate, while positive values (concave slopes) suggest areas with water runoff. The erosion processes are more intense on convex slopes while on the concave slopes eroded sediments are deposited. The lower basin of Uz is mostly characterized by convex surfaces (>60% of the surface) (Fig. 2D).

The highest flood risk is found in areas with anthropogenic interventions. Land use (16.04%) has an important contribution to the occurrence of floods. The studied basin is 66% covered by forests. The areas with anthropogenic interventions are situated along the valley of the Uz River (the localities of Salatruc and Darmanesti), and on the slopes corresponding to the valleys. In these areas, the flood production risk is very high (Fig. 2E). The aforementioned factors were reclassified. Subsequently, estimation was determined by their influence upon the occurrence of the floods. By applying the methodology described above, the flood potential index was obtained for the lower Uz River basin.

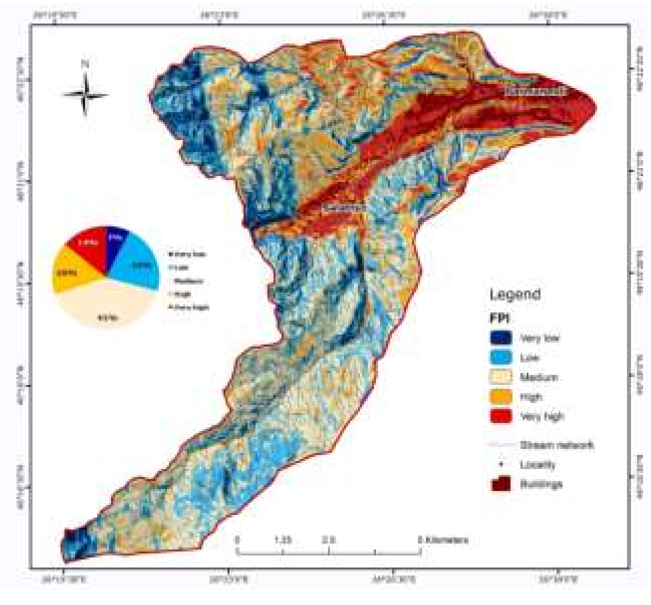

Fig. 3 - Map of the distribution of flood potential index (FPI) values in the lower Uz river basin

The FPI raster was grouped into five classes, using the *Natural Breaks (Jenks)* classification of the ArcGIS v.10.2.2 software. The first two classes included areas with lithological structure and soils with high water infiltration capacity, areas with high slope values (> 20°) and forested surfaces (Fig. 3).

The highest values of the index range between 3.96 and 4.71 and they account for 14% of the entire surface of the area (Table 2). The areas with the highest degree of exposure to floods are situated right near the Uz River. In a natural regime, flooding occurs most frequently because of waters spilling over the banks. The construction of the Poiana Uzului lake dam and of the other anthropogenic pressures upon the natural environment (extension of the inhabited area, the uncontrolled deforestation of forests, the extension of cultivated lands, etc) reduced the natural environment area, thus provoking a perturbation of the environment.

Tab. 2 Classification of natural and anthropogenic physical-geographic factors in the lower Uz river basin (FPI)

Estimation score	**1**	**2**	**3**	**4**	**5**
Class of FPI values	1.56 – 2.4	2.4 – 2.86	2.87 – 3.38	3.39 -3.95	3.96 – 4.71
FPI degree	Very low	Low	Average	High	Very high

Anthropogenic pressures and climatic changes implicitly create conditions for the outbreak of extreme phenomena, which have disastrous consequences. In the Uz basin during the floods, water accumulations with significant depths are encountered in lower altitude areas. The areas most vulnerable to floods are those with a marked anthropogenic intervention (the localities of Salatruc and Darmanesti). Vulnerability largely depends on the way lands are used, too.

The present study demonstrates that the major riverbed of the Uz River – in the lower sector, comprising the villages of Salatruc and Darmanesti – has a high flood risk. The main cause is represented by the lands with very low (quasi-horizontal) slopes, which have a high water retention capacity, as well as by anthropogenic intervention (i.e., the use of the major riverbed). A part of the risk is accentuated by the water coming from the Izvorul Negru creek, (a right-side tributary that with confluence downstream from the village of Salatruc).

Conclusions

It is important to identify the flood risk areas for protecting the population and for mitigating damage should extreme phenomena occur. The catchment basin of Uz is situated in an area with high vulnerability to hydrological risk phenomena.

From this perspective, it is worth highlighting the lower sector, situated downstream from Lake Poiana Uzului (that also has the role of mitigating flood waves).

The map comprising the distribution of flood index values underscores that the most affected areas are the human settlements of Salatruc and Darmanesti, situated in the immediate vicinity of the Uz River. They range between 3.96 and 4.71 and they account for 14% of the entire surface of the studied area (which does not represent a high value on a general scale). The elaboration of hydrological risk maps clearly demonstrates that human settlements are exposed permanently to the risk of floods, reason for which a proper management is mandatory. A change in the use of lands and the interdiction of building houses in floodable areas would contribute to the reducing of vulnerability. The renaturation of riverbeds would lead to a decrease in high water levels, especially during flood waves.

Riverbanks must be stabilized and dammed along the entire path affected by overflows. The Poiana Uzului reservoir determined a drastic reduction of the flood phenomenon downstream, but also an intensification of sediment accumulation processes at the outlet of the river into the lake. The micro-hydroelectric stations installed on the Uz River mitigate the effect of floods downstream, but they intensify it upstream, by creating temporary lakes (small in size, affecting limited areas).

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References

Barbulescu, A., Maftei, C. (2015). *Modeling the climate in the area of Techirghiol Lake (Romania)*. Romanian Journal of Physics, 60(7–8), 1163–1170.

Birsan, M.V., Zaharia, L., Chendes, V., Branescu, E. (2014). *Seasonal trends in Romanian streamflow*. Hydrological Processes, 28(15), 4496–4505.

Čech, M., Čech, P. (2013). *The role of floods in the lives of fish-eating birds: predators loss or benefit?.* Hydrobiologia, 717(1), 203-211.

Chendes, V., Corbus, C., Petras, N. (2015). *Characterisyics of April 2005 flood event and affected areas in the Timis-Bega Plain (Romania) analysed by hydrologic, hydraulic and GIS methods*. 15th International Multidisciplinary Scientific GeoConference. SGEM, 1, 121-128.

Chirila, G., Corbus, C., Mic, R., Busuioc, A. (2008). *Assessment of the Potential Impact of Climate Change upon Surface Water Resources in the Buzau and Ialomita*

Watersheds from Romania in the Frame of Cecilia Project. BALWOIS 2008, FY Republic of Macedonia, Ohrid, 1-7.

Cojoc, G., Romanescu, G., Tirnovan, A. (2015). *Exceptional floods on a developed river. Case study for the Bistrita River from the Eastern Carpathians (Romania)*. Natural Hazards, 77(3), 1421-1451.

Corduneanu, F., Vintu, V., Balan, I., Crenganis, L., Bucure, D. (2016). *Impact of drought on water resources in north-eastern Romania. Case study – the Prut River*. Environmental Engineering & Management Journal (EEMJ), 15(16), 1213-1222.

Corduneanu, F., Bucur, D., Cimpeanu, S.M., Apostol, I.C., Strugariu, Al. (2016). *Hazards Resulting from Hydrological Extremes in the Upstream Catchment of the Prut River*. Water Resources, 43(1), 42-47.

Costache, A., Comănescu, L., Nedelea, A. (2017). *Assessing Perception of Floods within the Framework of VULMIN Project: Methodological Remarks*. Annals of Valahia University of Targoviste, Geographical Series, 17(2), 145-151. doi:10.1515/avutgs-2017-0013.

Diaconu, D.C., Andronache, I., Ahammer, H., Ciobotaru, A.M., Zelenakova, M., Dinescu, R., Pozdnyakov, A.V., Chupikova, S.A. (2017). *Fractal drainage model - a new approach to determinate the complexity of watershed*. Acta Montanistica Slovaca, 22(1), 12-21.

Hapciuc, O.E., Romanescu, G., Minea, I., Iosub, M., Enea, A., Sandu, I. (2016). *Flood susceptibility analysis of the cultural heritage in the Sucevita catchment (Romania)*. International Journal of Conservation Science, 7(2), 501-510.

Hapciuc, O.E., Minea, I., Romanescu, G., Tomasciuc, A.I. (2015). *Flash flood risk management for small basins in mountain-plateau transition zone. Case study for Sucevita catchment (Romania)*. International Multidisciplinary Scientific GeoConference, SGEM, 301 – 308.

Komínková, D., Nábělková, J., Vitvar, T. (2015). *Effects of combined sewer overflows and Storm water drains on metal bioavailability in small urban streams (Prague metropolitan area, Czech Republic)*. Journal of Soils and Sediments, 1-15, DOI:10.1007/s11368-015-1327-8.

Langovic, M., Dedjanski, V. (2017). *Water Supply in the Republic of Serbia – State and Perspectives*. Annals of Valahia University of Targoviste, Geographical Series, 17(1), 28-36, doi:10.1515/avutgs-2017-0003.

Li, Z., Zhang, Y., Zhu, Q., He, Y., Uao, W. (2015). *Assessment of bank gully development and vegetation coverage on the Chinese Loess Plateau*. Geomorphology, 228(1), 462-469.

Li, Z., Zhang, Y., Zhu, Q., Yang, S., Li, H., Ma, H. (2016). *A gully erosion assessmentmodel for the Chinese Loess Plateau based on changes in gully length and area*. Catena, 148, 195-203. Doi.org/10.1016/j.catena.2016.04.018.

Lóczy, D., Mátrai, I., Fehér, G., Váradi, Z. (2014). *Ecological Evaluation of the Baja-Bezdan Canal (Hungary-Serbia) for Reconstruction Planning*. Water Resource Management, 28(3), 815-831.

Mierla, M., Romanescu, G., Nichersu, I., Grigoras, I. (2015). *Hydrological risk map for the Danube delta - a case study of floods within the fluvial delta*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 8(1), 98-104.

Miftode, I.D., Romanescu, G. (2016). *The variation of the liquid monthly average flow in the hydrographic basin of the Uz river*. Proceedings of the "Dimitrie Cantemir" Geographic Seminar, 41, 27-36.

Miftode, I.D., Romanescu, G., Profir, O. (2016). *The morphometric aspects of the Uz hydrographic basin*. Proceedings of the "Dimitrie Cantemir" Geographic Seminar, 41, 37-46.

Mihu-Pintilie, A., Romanescu, G. (2011). *Determining the potential hydrological risk associated to maximum flow in small hydrological sub-basins with torrential character of the river Bahlui*. Present Environment and Sustainable Development, 5(2), 255-266.

Mihu-Pintilie, A., Romanescu, G., Stoleriu, C. (2014). *The seasonal changes of the temperature, pH and dissolved oxygen in the Cuejdel Lake, Romania*. Carpathian Journal of Earth and Environmental Sciences, 9(2), 113-123.

Mu, Y., Mu, X. (2013). *Energy conservation in the Earth's crust and climate change*. Journal of the Air & Waste Management Association, 63(2), 150-160.

Radevski, I., Gorin, S. (2017). *Floodplain analysis for different return periods of river Vardar in Tikvesh valley (Republic of Macedonia)*. Carpathian Journal of Earth and Environmental Sciences, 12(1), 179-187.

Raška, P. (2015). *Flood risk perception in Central-Eastern European members states of the EU: a review*. Natural Hazards, 79(3), 2163-2179.

Reti, K.O., Malos, C.V., Manciula, I.D. (2014). *Hydrological risk study in the Damuc village, the Neamt county*. Journal of Environmental Protection and Ecology, 15(1), 142-148.

Romanescu, G. (2003). *Hidrologie generală*. Editura TERRA NOSTRA, Iaşi.

Romanescu, G. (2005). *Riscul inundaţiilor in amonte de lacul Izvorul Muntelui si efectul imediat asupra trasaturilor geomorfologice ale albiei*, Riscuri şi catastrofe, 4, 117-124.

Romanescu, G. (2006). *Complexul lagunar Razim-Sinoie. Studiu morfohidrografic*. Editura Universităţii „Alexandru Ioan Cuza", Iaşi.

Romanescu, G., Nistor, I. (2011). *The effect of the July 2005 catastrophic inundations in the Siret River's Lower Watershed, Romania*. Natural Hazards, 57, 345-368. Doi: 10.1007/s11069-010-9617-3.

Romanescu, G., Stoleriu, C., Romanescu, A.M. (2011). *Water reservoirs and the risk of accidental flood occurrence. Case study: Stanca–Costesti reservoir and the historical floods of the Prut river in the period July–August 2008, Romania*. Hydrological Processes, 25(13), 2056-2070.

Romanescu, G., Cotiuga, V., Asandulesei, A., Stoleriu, C. (2012). *Use of the 3-D scanner in mapping and monitoring the dynamic degradation of soils. Case study of the Cucuteni-Baiceni Gully on the Moldavian Plateau (Romania).* Hydrology and Earth System Sciences, 16, 953-966.

Romanescu, G., Zaharia, C., Stoleriu, C. (2012). *Long-term changes in average annual liquid flow river Miletin (Moldavian Plain).* Carpathian Journal of Earth and Environmental Sciences, 7(1), 161-170.

Romanescu, G. (2013). *Alluvial Transport Processes and the Impact of Anthropogenic Intervention on the Romanian Littoral of the Danube delta*. Ocean & Coastal Management, 73, 31-43.

Romanescu, G., Stoleriu, C. (2013a). *Causes and Effects of the Catastrophic Flooding on the Siret River (Romania) in July-August 2008*. Natural Hazards, 69, 1351-1367.

Romanescu, G., Stoleriu, C. (2013b). *An inter-basin backwater overflow (the Buhai Brook and the Ezer reservoir on the Jijia River, Romania).* Hydrological Processes, 28(7), 3118-3131.

Romanescu, G., Stoleriu, C. (2014). *Anthropogenic interventions and hydrological-risk phenomena in the fluvial-maritime delta of the Danube (Romania).* Ocean & Coastal Management, 102, 123-130.

Romanescu, G., Sandu, I., Stoleriu, C., Sandu, I.G. (2014). *Water Resources in Romania and Their Quality in the Main Lacustrine Basins.* Rev. Chim. (Bucharest), 65(3), 344-349.

Romanescu, G., Zaharia, C., Sandu, A.V., Juravle, D.T. (2015). *The annual and multiu-annual variation of the minimum discharge in the Miletin catchment (Romania). An important issue of water conservation.* International Journal of Conservation Science, 6(4), 729-746.

Romanescu, G., Tirnovan, A., Cojoc, G.M., Sandu, I.G. (2016). *Temporal variability of minimum liquid discharge in Suha basin. Secure water resources and preservation possibilities*. International Journal of Conservation Science, 7(4), 1135-1144.

Romanescu, G., Stoleriu, C. (2017). *Exceptional floods in the Prut basin, Romania, in the context of heavy rains in the summer of 2010.* Natural Hazards and Earth System Sciences, 17, 381-396.

Romanescu, G., Hapciuc, O.E., Minea, I., Iosub, M. (2017). *Flood vulnerability assessment in the mountain-plateau transition zone. Case study for Marginea village (Romania)*. Journal of Flood Risk Management, Doi: 10.1111/jfr3.12249.

Saaty, T.L. (1980). *The Analytic Hierarcy Process*, McGraw-Hill: New York, NY, USA.

Serban, G., Rus, I., Vele, D., Bretcan, P., Alexe, M., Petrea, D. (2016). *Flood-prone area delimitation using UAV technology, in the areas hard-to-reach for classic aircrafts: case study in the north-east of Apuseni Mountains, Transylvania*. Natural Hazards, 82(3), 1817-1832.

Siret Water Basin Administration, Archive. (2015). Raport. Siret Water Basin Administration, Bacau.

Smith, G. (2003). *Flash flood potential: determining the hydrologic response of FFMP basins to heavy rain by analyzing their physiographic characteristics*. http://www.cbrfc.noaa.gov/papers/ffp_wpap.pdf.

Solín, Ĺ., Feranec, J., Nováčk, J. (2011). *Land cover changes in small catchments in Slovakia during 1990-2006 and their effects on frequency of flood events*. Natural Hazards, 56, 195-214.

Stancalie, G., Craciunescu, V., Nertan, A., Mihailescu, D. (2012). *Contribution of satellite data to flood risk mapping in Romania*. IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 899-902.

Su, X., Nilsson, C., Pilotto, F., Liu, S., Shi, S., Zeng, B. (2017). *Soil erosion and deposition in the new shorelines of the Three Gorges Reservoir*. Science of the Total Environment, 599-600, 1485-1492.

Tirnovan, A., Cojoc, G.M., Romanescu, G., Obreja, F. (2014a). *Predicting the potential index of major floods production in the Suha basin (Suha Bucovineana)*. 2nd International Conference – Water resources and wetlands. Tulcea, 539 –545.

Tirnovan, A., Romanescu, G., Cojoc, G.M. (2014b). *The impact of Heavy Rainfall in the Hydrological regime of Suha River Basin in 2006*. Present Environment and Sustainable development, 8(2), 21-31.

Yang, H.C., Wang, C.Y., Yang, J.X. (2014). *Applying image recording and identification for measuring water stages to present flood hazards*. Natural Hazards, 74(2), 737-754.