THE SPATIO-TEMPORAL VARIABILITY OF MAXIMUM FLOW IN THE UZ HYDROGRAPHICAL BASIN

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Abstract. The analysis of the maximum flow, resulting from the influences of several miscellaneous control factors, leads to the empirical knowledge of the quantitative and qualitative hydrological characteristics of the rivers. The temporal and spatial variability of the maximum flow has been analyzed in this paper, based on the study of the monthly and annual maximum discharges recorded between 1985-2006, at the Valea Uzului, Cremenea, and Darmanesti hydrometric stations, in the Uz watershed. The data is provided by the Water Basin Administration Siret from Bacău which for this study was statistically processed. For the assessment of the maximum flows with different exceeding probabilities, the Pearson III empirical and theoretical curves have been utilized. The concluding results have been obtained using hydrologic regionalization relations; these take into account the specific maximum flows ($q_{maxp\%}$) with different insurances, the average altitude (H_m) and the area (F) of the drainage basin ($H_m/\sqrt{F}$). By selecting maximum flows with values exceeding the flooding stage (FS), the occurrence frequency has been established in the studied area. The highest floods in the Uz hydrographical basin have occurred in the months of June-July.

Keywords: maximum flow, maximum specific flow, Pearson III distribution low, exceeding probabilities, regionalization relations, Uz watershed

1. INTRODUCTION

The maximum flow represents one of the river's regime phases. The knowledge of the maximum discharges is important for designing, exploring and maintaining the hydrotechnical and other type of engineered works for defense against flooding. It has an important role in limiting the damages caused by flooding (*Sorocovschi, 2002*). The global climatic changes lead to increased efforts in investigating the flood related risks (*Mihăilă et al., 2009; Mustăţea, 2005; Olaru et al., 2010; Romanescu et al., 2011; Rotaru and Kolev, 2010; Stanciu et al., 2005*). The knowledge of the flash floods is considered to be the representation of the major natural risk factors (*Chiriac et al., 1980; Romanescu, 2009 a,b,c; Romanescu and Nistor, 2011*). The purpose of this paper is the analysis of the maximum flows' variability in correlation with different morphometric and climatic variables in the area of the Uz hydrographical basin, in Eastern Carpathian Mountains.

Knowing the peculiarities of the maximum flow variablility offers the possibility of solving the basic problems encountered during practical water planning and rational use *(Bîrsan et al., 2014; Diaconu, 1988; Diaconu and Şerban, 1994).* The need to study

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the spatial and temporal variability of the maximum flow in the Uz watershed is important because in last decades it has been ravaged by floods with major social and economical consequences. In the Uz hydrographic basin the historical maximum flow was 229 m^3/s, registered in July 2005, at Cremenea hydrometric station. The value of the flow exceeded 57 times the value of the multiannual average flow.

2. STUDY AREA

The Uz hydrographical basin has a total surface of 475 km^2. It is situated in the south-eastern part of Romania, in Eastern Carpathian Mountains (Fig. 1). The river Uz is part of the right tributaries of the river Trotus. It springs from the Ciucului mountains from an altitude of 1165.12 m a.s.l. and has a length of 46 km. It flows into the river Trotus at an altitude of 319.79 m a.s.l. .

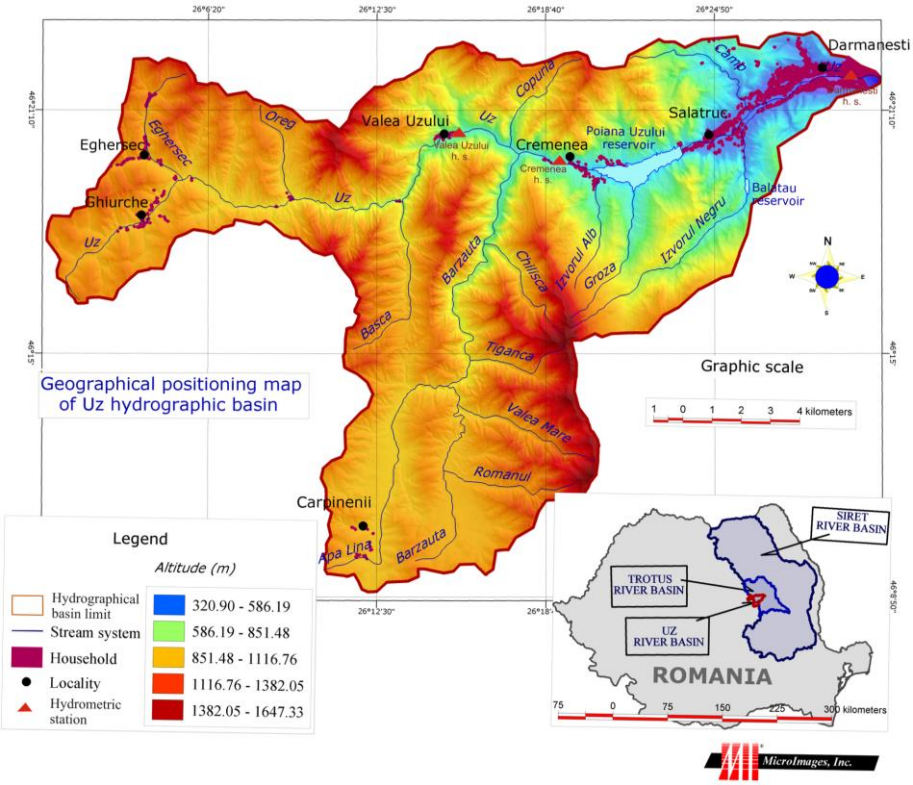

Fig. 1. ***The Uz watershed and its location in Romania, and within the Trotuş and Siret Rivers' catchments***

Mathematically the Uz hydrographical basin falls between 26˚00'16" and 26˚30'56" eastern longitude and between 46˚08'44"and 46˚23'27" northern latitude. The Uz basin stretches out between the maximum altitude of 1647.18 m a.s.l. and the minimum altitude of 319.21 m a.s.l. The average altitude of the basin is that of 969.54 m.

The river Uz and its tributaries have a big contribution to the fragmentation of the landscape and to the creation of its current energy. The North-South orientation of the Nemira-Șandru Mare slope influences the flow direction of the waterflow. The lower terraces are separated from the medium ones by sharp slopes. The declivity of the slopes varies between 5 and 50º, and between 1 and 3º in the meadows sectors. On the interfluves and on the terrace bridges the values of the declivities varies between 0 and 6º.

The Uz hydrographical basin has a climate specific to the medium heights of the Eastern Carpathian Mountains. However, it is also similar to a depression climate (shelter climate) which manifests itself in the Darmanesti Depression. The average multiannual temperature registered at the Tg. Ocna meteorological station assisting the Uz hydrographic basin, registers values of +9.4°C. Some of the hydroclimatic features of the Uz basin are highlighted in Table 1.

Table 1. ***Hydroclimatic features of the Uz basin (Source: Water Basin Administration Siret, 2015)***

River	Hydrometric station	Multiannual precipitations (l/m^2)	Multiannual flow (m^3/s)	Hystorical maximum flow (m^3/s)
Uz	Valea Uzului	622.0	1.68	78.3/12.07.2005
	Cremenea	705.9	4.02	229/12.07.2005
	Darmanesti	623.3	4.90	132/13.07.2005

On the river Uz, the Poiana Uzului anthropic reservoir was designed for supplying water to downstream settlements and put into operation in 1972. On the Izvorul Negru brook, a natural pond has been formed (Bălătău).

3. MATERIALS AND METHODS

For the analysis and data processing, hydrological, analytical, geostatistical and GIS methods have been used. The maps have been drawn using the TNTMips v.6.9 and ArcGIS v.10.2.2. The spatial database includes the topographic map 1:25000, elaborated by the Romanian Military Topographic Directorate, the DTM 1:5000, different vector layer obtained through 1:5000 ortophotoplans.

It was analyzed and processed the data registered at three hydrometric stations: Valea Uzului, Cremenea and Darmanesti located on the Uz River (Table 2).

Table 2. ***Data specific to the analysed hydrometric stations in the Uz hydrographical basin*** (Source: Water Basin Administration Siret, 2015)

River	Hydrometric stations	Establishment date	Distance from the confluence (km)	Distance from the spring (km)	Drainage basin		Studied period
					Area (km^2)	Altitude (m)	
Uz	VALEA UZULUI	1967	22	28	150	1070	1985-2006
	CREMENEA	1976	16	34	337	1070	
	DARMANESTI	1976	7	43	404	975	

The data was provided by the Water Basin Administration Siret from Bacău. The assessment of the maximum flows with different exceeding probabilities was possible by the plotting of the theoretical and empirical distribution curves (Pearson III). Hydrologic regionalization relations have been established, taking into account the maximum discharges with different insurances ($q_{maxp\%}$), the average altitude (H_m) and the area (F) of the drainage basin ($H_m/\sqrt{F}$).

The flood occurrence frequency has been computed based on the selection of the maximum flows with values higher than those corresponding to the flooding stage (FS).

4. RESULTS AND DISCUSSIONS

Maximum flows. The maximum leak in the Uz hydrographic basin is generated by rains accompanied sometimes by snow melting. There is interdependence between the maximum leak and the area related to the hydrometric stations. In the Uz hydrographic basin the specific flow varies depending on the positioning and the size of the surface related to the hydrometric station. In the Darmanesti depression zone, the specific flow has lower values than in the mountainous region (Valea Uzului and Cremenea) (Table 3).

Table 3. ***The variation of the specific flow***

Hydrometric station	Surface of basin (km^2)	Specific maximum flow ($l/s/km^2$)
Valea Uzului	150	178.1
Cremenea	337	169.1
Darmanesti	404	78.8

In the mountainous sector, the maximum leak occurs during summer, and in the depression sector it occurs during spring. This fact confirms the connection between the precipitations and the maximum flows which sometimes is associated with snow melting (Fig. 2).

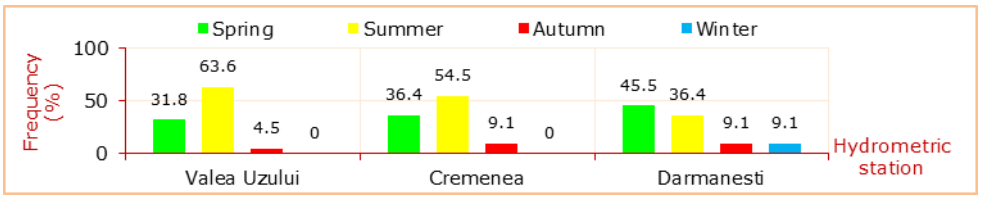

Fig. 2. ***The maximum percentage leak by season on the river Uz (1985-2006)***

The interannual variability of the maximum flows (1985 – 2006). The Figure 3 highlights the variability of the river Uz maximum flow. The highest values of the maximum flows occurred during the 2005 flash floods at all three hydrometric stations. The highest values of the maximum flows have been registered on the Uz river during the years 1988, 1991, 1996, 1998 and 2001. The extent of the flows from these years has been moderate in comparison with 2005. At the level of the entire basin, the highest historical value has been registered on July 12th 2005 at Cremenea station (229 m^3/s), exceeding 57 times the multiannual average flow (4.02 m^3/s). The smallest value (6.22 m^3/s) has been registered at Darmanesti station in 1989, exceeding 1.3 times the average multiannual flow (4.9 m^3/s).

The occurrence of exceptional maximum flows registered in 2005 for the entire Uz basin proves the fact there is a connection between the torrential character of the precipitations and the maximum flows of the river Uz.

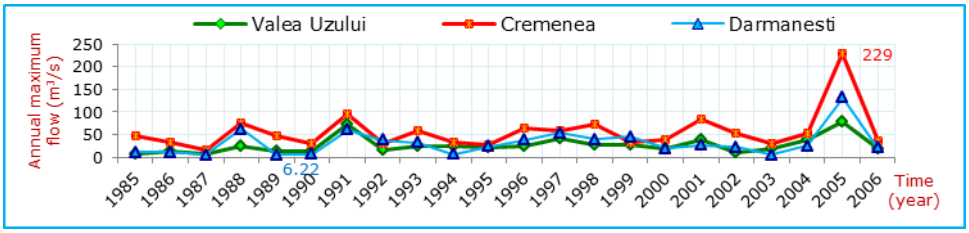

Fig. 3. ***The interannual variability of the maximum annual flows on the river Uz***

The variation coefficients (Cv) have been computed as a percentage ratio between the linear and the arithmetic average of the series including the annual maximum flows from each station. From the computation resulted in the following values : Valea Uzului – 48.05%, Cremenea – 45.12%, Darmanesti – 62.15%. The higher the coefficients tends towards 100%, the more intense is the variation, the more heterogenous the collectivity is, while the average has a lower level of representation (*Jaba, 2002*). The resulting values of the variation coefficients indicate a high variability of the maximum values for the entire basin.

The maximum flows with different exceeding probabilities. For designing, executing and exploiting the hydrotechnical works, it is imperative to know some hydrological elements (flows, levels, volumes, etc.) with various probabilities of computation and verification. Using the Weibull formula $p_i = i/(n+1)$ in which: i is the rank number of the value from the series of data ordered in a descending way, and n is the actual number of the data series, the p empirical probability was estimated. The probability curve thus obtained presents a significant importance. It indicates the values of the analyzed hydrological magnitude with desired probabilities *(Giurma et al., 2009*).

The assessment of the maximum flows with different exceeding probabilities (0.01%, 0.1%, 1%, 5% and 10%) have been determined using the theoretical Pearson III distribution curves. Based on the maximum flows with different exceeding probabilities (p%) the maximum specific flows of different insurances ($q_{maxp\%}$), have been computed, then correlated with the basin's morphometric parameters (H_m, F) or with their ratio ($H_m/\sqrt{F}$). Thus, the following correlations have been established: $q_{max\ p0.1\%}$- f(F), $q_{max\ p\%}$ - ($H_m/\sqrt{F}$). In the Uz hydrographical basin the maximum flow with the probability of 0.1% depends on the $H_m/\sqrt{F}$ ratio and varies between 805.64 l/s/km^2 at Valea Uzului, 858.95 l/s/km^2 at Cremenea and 805.64 l/s/km^2 at Darmanesti. The plotted curves (Fig. 4) offer the possibility of determining the values of the distinctive maximum runoff with several exceeding probabilities for any section.

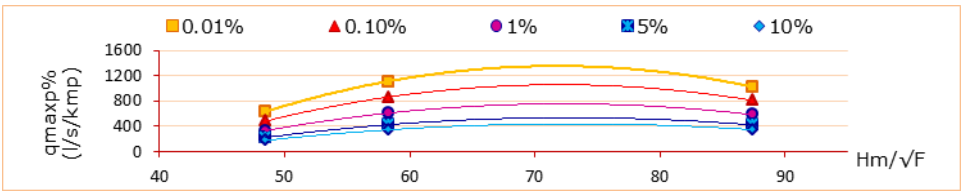

Fig. 4. ***The regionalization relation between the maximum flows ($q_{maxp\%}$) and the parameter - $H_m/\sqrt{F}$ in the Uz hydrographical basin***

In this case the graphic interpolation between two consecutive stations has been used, knowing the values of the basin's main morphometric elements. The points' arrangement on the basin's surface highlights the way in which the regionalization relations distinguish themselves at the scale of the basin.

At the spatial scale of the whole hydrographical basin, the map representing the zoning of the regionalization relations has been drawn in relation to the specific 0.1% probability maximum flow (Fig. 5).

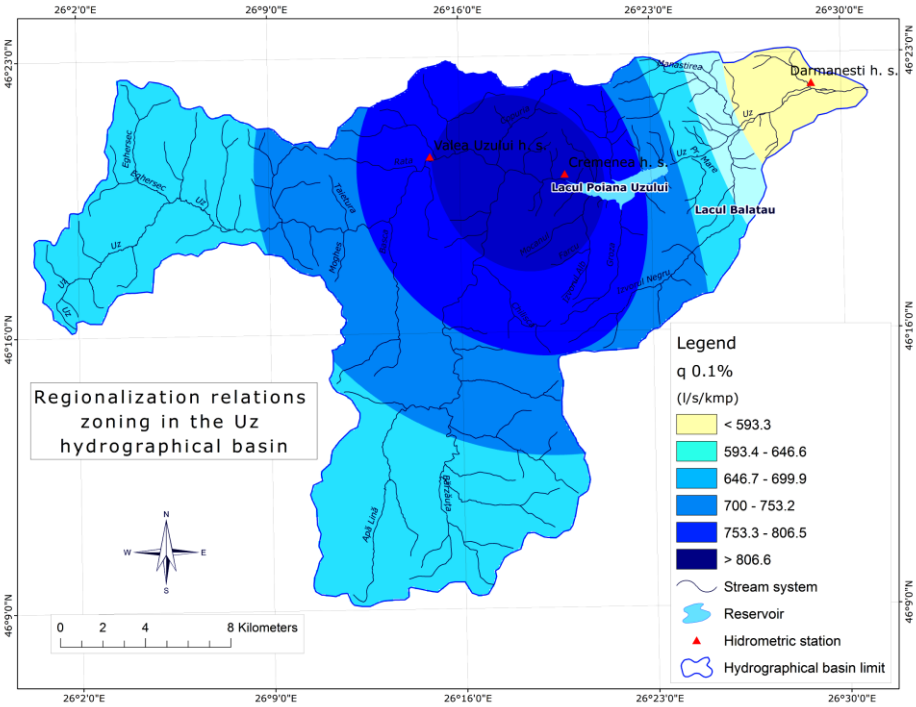

Fig. 5. ***The mapping of the regionalization relations for the p=0.1% in the Uz hydrographical basin***

Analyzing the spatial distribution of the specific maximum flow, one can notice that in the Uz hydrographical basin the values of the maximum flows fall within the variation gap between 479.1 and 646.6 l/s/km^2. The smallest values (>593.3 l/s/km^2) are registered in the eastern extremity of the Uz basin river (Darmanesti locality), where the precipitation quantity was reduced. The highest of the specific maximum flow (753.3-859.8 l/s/km^2) can be found in the areas with the highest altitudes of the basin, including Valea Uzului and Cremenea localities. In these areas are registered important quantities of precipitation. The southern and the western part of the basin (Bodoc Plateau and Ciucului Mountains) is characterized by a specific maximum flow varying between l/s/km^2. For the interpolation the Kriging method (ArcGIS) has been used.

The plotting of the specific maximum flows, q_{max} (l/s/km^2) can also be made in relation with the area F (km^2) of the drainage basin (*Diaconu and Şerban, 1994)*. For the Uz catchment a selection of specific flows with the exceeding probabilities of 0.1%

and 1% was made; the aim of this selection was to illustrate the regionalization relation of the specific maximum flows dependent on the basin's surface (Fig. 6).

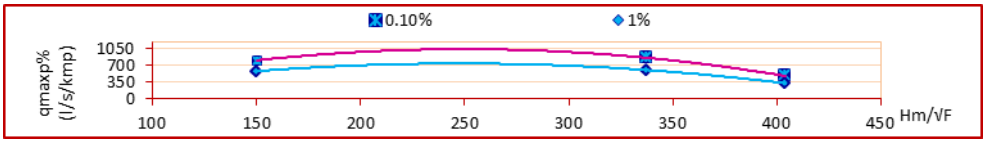

Fig. 6. ***The regionalization relation between the maximum flows (qmaxp%) and the areas of the catchments (F) in the Uz hydrographical basin***

The flash floods ocurrence frequency. In order to study the flood frequency, the flash floods occurred at the Cremenea and Darmanesti hydrometric stations have been analyzed (1985-2006). These stations have data for the defense andflooding stages. Thus, the flash floods having their maximum level exceeding the flooding stage (FS=200 cm at Cremenea; FS=200 cm at Darmanesti) were taken into account. Thus, in the analysed period, the flood occurrence frequency has been computed. The numbers of cases exceeding the flooding stage are 48 at Cremenea station and 44 at Darmanesti. At Cremenea station a maximum annual number of three flash floods in 1986, 1991, 1992, 1993, 1995, 2000 and 2001 has been registered. At Darmanesti station the maximum number was limited to three flash floods in 1987, 1991, 1992, 1998 and 2000 (Fig. 7).

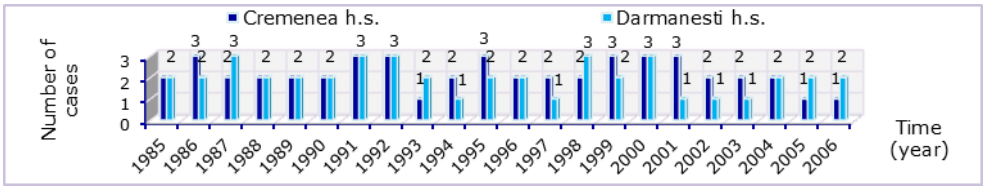

Fig. 7. ***The annual occurrence frequency of the flash floods (in number of cases) having their maximum level exceeding the flooding stage***

The monthly occurrence frequency which has exceeded the flooding stage has the highest values during the month of June at Cremenea station and the months of July at Darmanesti station (Fig. 8).

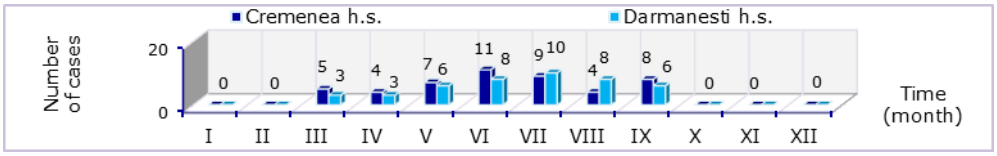

Fig. 8. ***The monthly occurrence frequency of the flash floods (in number of cases) having their maximum levels exceeding the flooding stage***

The phenomenon is due especially to heavy rains fallen during the warm season. The flash floods are more frequent at Cremenea hydrometric station (mountainous zone) situated upstream of Poiana Uzului reservoir, where the river bed is narrower and the precipitations are higher in quantity.

Downstream of the dam, in the corresponding area of the Darmanesti depression, the Uz riverbed widens in proximity with the confluence of the river Trotus. In this case the flash floods are less frequent.

5. CONCLUSIONS

The temporal and spatial variability of the maximum flow has been analysed in the Uz River watershed. For knowing the specific maximum flows with different exceeding probabilities in the sections where there is no hydrological control, the type q-f (Hm/√F), q-f regionalization relations have been implemented. The highest values of the maximum flows (1% probability) can be found in the basin's high mountainous regions. Exceeding the flooding stages during the floods in July 2005 at the Cremenea station and during July and August at Darmanesti station was due to the heavy rains. The biggest unique flash floods occurred at the scale of the entire hydrographical basin in July 2005. In this case, the link between the torrential character of the precipitations and the maximum flows of the river has been proven. The existence of the 2005 exceptional floods has shown the necessity of performing hydrotechnical engineering works. The flash floods occurrence frequency at a monthly scale is typical for the summer months.

REFERENCES

1. Birsan M.V., Zaharia L., Chendes V., Branescu E. (2014), *Seasonal trends in Romanian streamflow*. Hydrological Processes, 28(15):4496–4505.
2. Chiriac V, Filoti A, Manoliu I.A. (1980), *Prevenirea si combaterea inundatiilor*, Editura Ceres, București.
3. Diaconu C. (1998), *Râurile de la inundații la secetă*, Editura Tehnică, București
4. Diaconu C., Șerban P. (1994), *Sinteze și regionalizări hidrologice*, Editura Tehnică București.
5. Giurma I., Crăciun I, Giurma C.R. (2009), *Hidrologie și hidrogeologie-aplicații*, Editura Politehnium, Iași.
6. Jaba E. (2002), *Statistică – Ediția a treia revizuită și adăugită*, Editura Economică, București.
7. Mihăilă D., Bostan D., Tănasă I., Prisacariu A. (2009), *The precipitations of the superior basin of the Prut and the floods of july – august 2008 in the Oroftiana – Stanca sector. Causes, peculiarities and impact on the environment*. Present Environment and Sustainable Development 3: 169-179.
8. Mustățea A. (2005), *Viituri excepționale pe teritoriul României,* Editura Institutului Național de Hidrologie și Gospodărire a Apelor, București 409.
9. Olaru V., Voiculescu M., Georgescu L.P., Coldararu A. (2010), *Integrated management and control system for water resources*, Environmental Engineering and Management Journal 9(3): 423-428.
10. Romanescu G. (2009a), *Siret river basin planning (Romania) and the role of wetlands in diminishing the floods*, WIT Transactions Ecology and the Environment 125: 439-453.
11. Romanescu G. (2009b), *Evaluarea riscurilor hidrologice*, Editura Terra Nostra, Iași.

12. Romanescu G. (2009c), *Trophicity of lacustrine waters (lacustrine wetlands) on the territory of Romania*. Lakes, reservoirs and ponds 3: 25-39.
13. 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.
14. Romanescu G., Stoleriu C., Romanescu A.M. (2011), *Water reservoirs and the risk of accidental flood occurrence. Case study: Stânca-Costești reservoir and the historical floods of the Prut river in the period July-August 2008*, România. Hydrological Processes 25: 2056-2070. Doi: 10.1002/hyp.7957.
15. Rotaru A., Kolev C. (2010), *Addressing issues of geoenvironmental risks in Dobruja*, România/Bulgaria. Environmental Engineering and Management Journal 9(7): 961-969.
16. Sorocovschi V. (2002), *Hidrologia uscatului*, Casa Cărții de Știință, Cluj-Napoca.
17. Stanciu P., Nedelcu G., Nicula G. (2005), *Hazardurile hidrologice din România*, Natural and anthropogenic hazards 5(23): 11-17.
18. *** Administrația Bazinală de Ape Siret. (2015), *Raport. Administrația Bazinală de Ape Siret*, Bacău.