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TEMPORAL VARIABILITY OF MINIMUM LIQUID DISCHARGE IN SUHA BASIN. SECURE WATER RESOURCES AND PRESERVATION POSSIBILITIES

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Abstract

The last climatic years have recorded a recrudescence of risk phenomena, especially floods and droughts. Because of this reason an acute shortage of water is presently felt even in the mountainous areas. Hydrological data have been recorded at 5 gauges distributed in the middle and lowers sectors of the basin. Suha river basin includes a large number of inhabitants, attracted here some time ago by mining exploitations. The closing of Ostra mine has not led to a decrease in population, and thus water demands are higher and higher and underground resources are used. Minimum discharge in the basin is extremely low in comparison to the reality of other mountain catchments (at Stulpicani gauge a mean minimum discharge of 0.611 m^3/s has been recorded during 1970-2013). This situation is due first of all to the rapid infiltration of water in the very permeable deposits (sands, gravels, boulders). An increase in water demands is probable if the comfort of the dwellings is improved by raising the number of baths and showers, of greenhouses for vegetables growing, of guest-houses with pools etc. In order to preserve water resources in the area is imposed the keeping of the present forested surfaces and the adequate control of tailings dumps so as to avoid underground and surface water pollution. Due to practices like toilets lacking septic tanks or gathering of manure on un-isolated platforms, the conservation of present water quality (especially the underground one) is imperious.

Keywords: *Water demands; Discharge; Surface flow; Hydrologic drought; Meteorological drought*

Introduction

In order to evaluate water resources, medium annual discharge ensures a 50% error. Minimum annual discharge represents the most important analysis in evaluating secure surface water resources. The evaluation of minimum discharge ensures a 90% prediction of water resources from certain areas and at the same time of quantity and quality conservation. Because of this reason studies regarding minimum discharge are numerous, but unfortunately not for all rivers in Romania. At the international level exists a permanent and long-time research regarding ways of water supply control and preservation [1-14].

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Suha river basin has a reduced surface and thus hydrologic studies approaching it are scarce. The most important analyses on the discharge regime and the conservation of water resources in Suha basin have only been conducted during the last years [15-18]. Institutional or private studies in Romania and implicitly in the north part of the Eastern Carpathians have approached water quality [19-33] or the management and preservation of water resources [34-52].

Geographic location

Suha river basin is positioned in the Eastern Carpathians and corresponds mostly to the flysch deposits of Stanisoara Mountains. Only its western extremity includes crystalline rocks of the Rarau Massif. It occupies the southern part of Obcina Feredeului, the south-eastern part of Rarau Massif, the eastern part of Ostra and Suha Mts. and the north-western part of Obcina Voronețului. Giving the name of the basin, the main river is Suha, who springs from under Ostra Peak at 1382 m altitude. Suha has the following tributaries: Brateasa, Botosana, Muncelu, Gemenea (who receives in its turn Slatioara brook), Ursoaia, Valea Seaca, Doroteia, Branistea, Negrileasa etc. (Fig. 1).

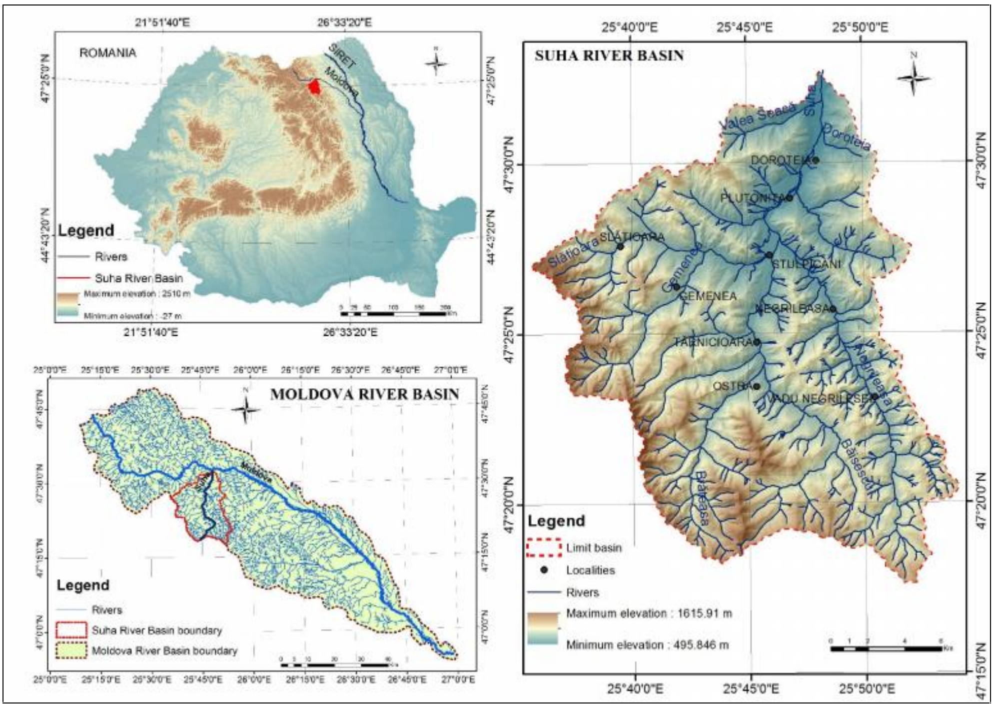

Fig. 1. Geographic location of Suha river basin

With a surface of 365 km^2, Suha river basin is part of the larger Moldova basin, and is limited by the following sub-hydrographic basins: Bahna, Salatruc, Sandru, Valea Caselor, Chiril, Crucea, Lesu, Holda, Holdita, Cotargas, Sabasa, Suha Mare, Suha Mica and Voronet [15-18].

Materials and methods

Hydrological data have been provided by Siret Basin Water Administration (Bacau) and processed in the Geoarcheology Laboratory of the Faculty of Geography and Geology from Iaşi. Measurements have been conducted at 7 gauges: Valea lui Ion, Valea Ursului, Slatioara 3, Gemenea 5, Gemenea 2, Gemenea 1, Stulpicani and Vadu Negrilesei. Data from the 8th gauge, Ursoaia, have not been taken into consideration in the present study due to the short period of observations (Fig. 2). In the analyzed basin, the observation and measurement points have varied as location and period. The oldest observations and measurements have begun in 1970 with the commissioning of the 14 gauges emplaced on Valea Ursului, Valea lui Ion, Slatioara, Plotonita, Gemenea, Hojda, Ostra, Baisescu, Paraul Lung, Negrileasa and Arsita rivers, followed in 1973 by Stulpicani gauge on Suha and in 2009 by Ursoaia gauge on the same river. In time, the number of gauges suffered some reorganization.

For the water pollution degree, data have been used from Siret Basin Water Administration and from our own determinations conducted during 2012-2015 (already published). Information on human settlements, number of inhabitants and land use are provided by city halls and satellite images.

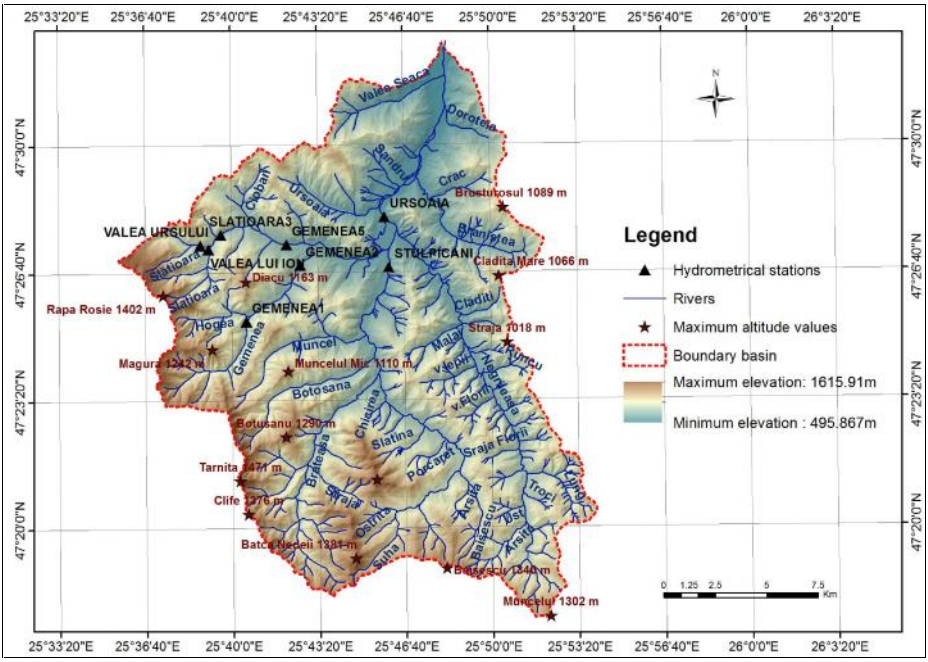

Fig. 2. Geographic location of gauges in Suha basin

Results and discussions

Minimum discharge represents a very complex phenomenon which presents different aspects in what regards duration, territorial repartition as well as proportions. In Romania, this phenomenon is registered most often during August-September due to reduced precipitations and high evapotranspiration. Minimum discharge is known in domain references as base flow (*etiaj* in romanian) [50]. The phenomenon is also manifested in winter, when it is amplified on two thirds of the Romanian territory (with the exception of the south-western region). This period presents very low discharge values because of mean temperatures generally lower than 0°C and of solid precipitations that participate in the flow process only if positive temperatures are registered.

Similar to the periods with high or exceptional water levels are treated and analyzed and those with very low levels or hydrological drought. A series of laws and manuals have been issued in Romania that synthesizes the measures of prevention, action and rehabilitation of hydrological drought: Government Emergency Ordinance nr. 21/2004, Law nr. 7/1996, Law nr. 481/2004, Government Decisions nr. 2288/2004, nr. 1176/2005, nr. 846/2010, Government Ordinance nr. 82/2011, Government Decisions nr. 271/2012 and 270/2012, the Common Order of the ministries of Internal Affairs and Environment and Forests nr. 254/3403/2012 etc. [15-18, 37, 38, 43]. All these laws in fact approach ways of conserving surface or underground waters.

Drought is a hydrological phenomenon that manifests slowly, progressively and constant, but which can have severe repercussions on population and economy. The occurrence of this hydrologic phenomenon is mainly due to the lack of rainfall. Two periods with precipitations deficit have been separated: dry periods in which precipitations have not been recorded for at least 5 consecutive days, and hydrologic drought periods in which precipitations are not recorded for at least 14 (during October-March) or 10 consecutive days (during April-September).

The analysis of the variability of liquid discharge is needed to establish the way river water is used and also to evidence river alimentation capacity from underground waters. From this point of view an exact estimation on water reserves can be done and thus an adequate utilization program. Emm. de Martone (1926) [53] has established a relation between the distribution of precipitations and river discharge rates by introducing the K aridity index, where: $K = P/(T+10°C)$. In the conditions of the medium latitude temperate climate the precipitations quantity has to be of minimum 250 mm for river network to have a permanent character. In the case of drought are delineated several stages and parameters: meteorological drought, when $P < ETP < ETR$, $P \rightarrow 0$; pedologic drought, when $RU+P\text{-}ETRv = 0$, $RU \rightarrow 0$; river drought, when $Q \rightarrow 0$; phreatic drought, when $Qs \rightarrow 0$; hydraulic reservoirs drought, when $LU \rightarrow 0$ (Lambert et al., 1989 cited by [15-18]). Where: P = precipitation quantity; ETP = potential evaporation; ETR = real evaporation; RU = soil available water reserve; Qs = underground discharge; Q = river discharge; Lu = available water reserves in reservoirs. In the analysis of the situations manifested in Suha basin, as well as for calculating occurrence probabilities, are used statistical data rows (as in the case of maximum discharge rates).

In the periods with low precipitations rivers are alimented only from underground input, and the quantity of water is reduced or even missing. On certain river sectors (medium and lower), where the coarse alluvial deposits are consistent and the water quantity reduced, it infiltrates in the floodplain bed and determines drought. The lack of water can also be due to domestic or industrial supply. From the analysis of the precipitation quantities registered at the gauges in Suha basin as well as in the entire Siret basin, it can be noticed that the years with the lowest precipitation quantities have been 1969, 1974, 1978, 1983, 1987 and 2001. The discharge rates in Suha basin have presented deficits up to September including. During the summer, but also winter months, have been river sections with no surface runoff. October and November have registered discharge rates much lower than the mean annual value, and lower even than the minimum value in the recorded data.

During 1970-2013 at Stulpicani gauge has been recorded a mean annual minimum discharge of $0.611m^3/s$. The mean annual minimum discharge rates have values of: $0.429m^3/s$ in January; $0.494m^3/s$ in February; $1.08m^3/s$ in March; $2.74m^3/s$ in April; $2.75m^3/s$ in May; $2.82m^3/s$ in June; $2.50m^3/s$ in July; $2.31m^3/s$ in August; $1.33m^3/s$ in September; $0.777m^3/s$ in October; $0.586m^3/s$ in November; $0.525m^3/s$ in December. The mean monthly minimum discharge rates are of: $0.275\ m^3/s$ in January; $0.302\ m^3/s$ in February; $0.389m^3/s$ in March; $1.09m^3/s$ in April; $0.952m^3/s$ in May; $0.905m^3/s$ in June; $0.869m^3/s$ in July; $0.750m^3/s$ in August; $0.633m^3/s$ in September; $0.475m^3/s$ in October; $0.372m^3/s$ in November; $0.319m^3/s$ in December (Fig. 3).

The smallest (historical) values of monthly minimum discharge rates have been identified: January 0.035m^3/s in 2004; February 0.037m^3/s in 1994; March 0.080m^3/s in 2006; April 0.200m^3/s in 1994; May 0.150m^3/s in 1989; June 0.125m^3/s in 1971; July 0.155m^3/s in 1971; August 0.162m^3/s in 1990; September 0.098m^3/s in 1990; October 0.132m^3/s in 1990; November 0.109m^3/s in 1988; December 0.043m^3/s in 1989. In Suha basin the phenomenon of hydrologic drought manifested in 1969, 1974, 1978, 1983, 1987 and 2001. These cases have been isolated, developing on small areas: on Gemenea river at Gemenea 2 gauge the smallest historical discharge of 0.000m^3/s has been recorded of 02.03.1969 and also on 01.10.2001. On the same river at Gemenea 1 station the minimum historical discharge was recorded on 08.12.1969. On Slatioara at Gemenea 5 hydrometric station the minimum historical discharge of 0.000m^3/s was recorded on 23-25.01.1974. At Slatioara 3 station the minimum historical discharge recorded has been of 0.008m^3/s on 13.01.1978. At Valea Ursului hydrometric station the minimum historical discharge has been of 0.001m^3/s on 15.12.1983. At Valea lui Ion station the minimum historical discharge recorded has been of 0.006m^3/s on 08-25.09.1987. On Suha river the minimum historical discharge rates have been registered in 2001 and had values of 0.035m^3/s and 0.009m^3/s at Stulpicani hydrometric station on 17-24.01.2001.

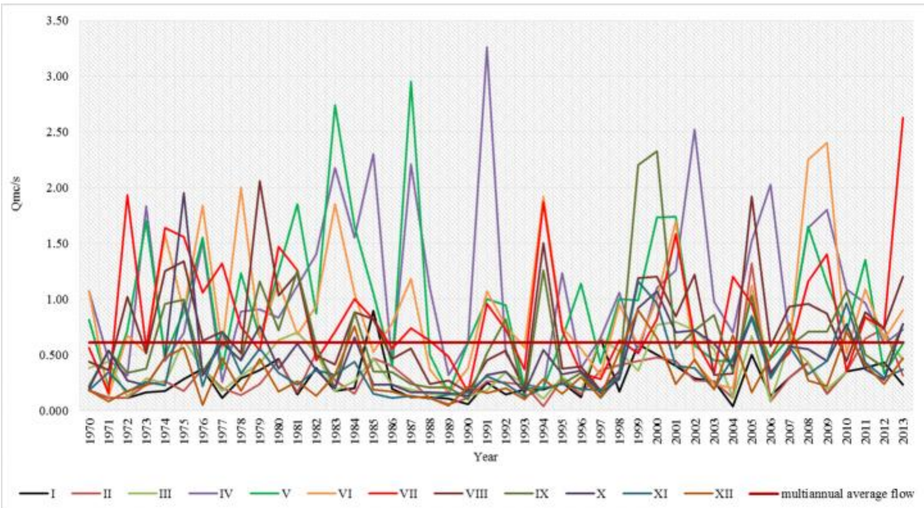

Fig. 3. Oscillations of monthly annual minimum discharge rates at Stulpicani gauge (Suha river)

On Slatioara river, between Slatioara 3 (where the upstream basin surface is of 18.6km²) and Gemenea 5 hydrometric stations (upstream basin surface of 33.5km²) are lost important water quantities. In the case of mean monthly minimum discharge rates with a 95% insurance the value from the Gemenea five hydrometric station is with 20.0L/s smaller than that from Slatioara three station, although the surface of the afferent hydrographic basin is much larger, close to double. In the case of mean daily minimum discharge rates with a 95% probability the difference is of 8.0L/s. In certain years, during the periods with small water levels the differences between the two hydrometric stations are much higher. For example in 1986, a droughty year, in July and August at Slatioara three hydrometric station the mean monthly discharge rates have been of 30.0-35.0L/s, while at Gemenea 5 in the same period they have been of only 10.0-12.0L/s.

For the sectors with active infiltration in the floodplain bed complete drought can occur. Still it is not a proper drying up in the sense of absence of precipitation or upstream input, but of underground losses favored by the high permeability of the floodplain deposits. In some sectors reduced discharge can occur, but then it again stops downstream. The minimum values ensured are used for different projects of water supply, for fisheries or for evacuating wastewater. The mean minimum monthly discharge with an 80% insurance is taken into consideration for the emplacement of fisheries, while the mean monthly minimum discharge is taken into consideration for wastewater evacuation so as to ensure dilution (it is also named dilution discharge).

The EU provisions do not admit drinkable water supply from surface sources, with the exception of special situations. This fact is according to the local or regional realities. In this case, the base for ensuring water supply is the mean daily minimum discharge with an 80% probability. For a more detailed analysis of the drying-up phenomenon have been computing, using the Pearson type III method, the minimum discharge rates with different occurrence probabilities for the eight hydrometric stations in Suha basin (Tables 1, 2).

Table 1. Values of minimum monthly discharge rates with diverse occurrence probabilities at the hydrometric stations in Suha basin

River	Gauge	Surface (km^2)	The minimum monthly flow (L/s) 80%	90%	95%	97%
Slatioara	Valea lui Ion	6.7	12.8	10.2	8.2	7.2
Slatioara	Valea Ursului	6.1	8.5	5.8	4.0	3.0
Slatioara	Slatioara 3	18.6	33.0	29.0	27.0	25.0
Slatioara	Gemenea 5	33.5	21.0	13.0	7.0	4.0
Gemenea	Gemenea 1	14.5	26.0	23.0	21.0	19.0
Gemenea	Gemenea 2	30.4	38.0	29.0	24.0	20.0
Suha	Stulpicani	131	75.0	130	105	90.0
Negrileasa	Vadu Negrilesei	129	45.0	90.0	75.0	65.0

Table 2. Values of minimum daily discharge rates with diverse occurrence probabilities at the hydrometric stations in Suha basin

River	Gauge	Surface (km^2)	Annual daily minimum flow (L/s) 80%	90%	95%	97%
Slatioara	Valea lui Ion	6.7	10.8	8.8	7.2	6.2
Slatioara	Valea Ursului	6.1	6.0	3.4	1.4	0.6
Slatioara	Slatioara 3	18.6	20.0	14.0	10.0	8.0
Slatioara	Gemenea 5	33.5	8.0	5.0	2.0	1.0
Gemenea	Gemenea 1	14.5	22.0	18.0	16.0	15.0
Gemenea	Gemenea 2	30.4	26.0	19.0	15.0	13.0
Suha	Stulpicani	131	80.0	52.0	38.0	30.0
Negrileasa	Vadu Negrilesei	129	45.0	30.	28.0	15.0

Unfortunately, during the last years the frequency and intensity of climatic and hydrologic risk phenomena have increased. Both on Suha and its tributaries have been recorded exceptional floods in 1975, 1981, 1984, 1991, 2005, 2006, 2007, 2008 and historical droughts in 1969, 1974, 1978, 1983, 1987, 2001. These extreme events in Suha basin are comparable to those that usually take place in the higher area of Siret river basin (rarely influenced by some local particularities).

Suha basin has a very high density of population, which has extended its urban and rural area along the main river network. In 2011 the population was of 5702 inhabitants in Frasin (town), 6201 in Stulpicani (26.5 inhabitants/km^2 density) and 3241 in Ostra (28.0 inhabitants/km^2) communes. The entire hydrographic basin has a population of 15144 inhabitants and a mean density of 42.5 inhabitants/km^2. The mountainous areas of the Eastern Carpathians usually have mean population densities of 10-20 inhabitants/km^2 [15-18] (Fig. 4).

The reduced liquid discharge of the river is insufficient for the water supply of all the residences. Because of this an important water quantity is exploited from underground resources (which originate from surface flow). The supplementary water quantity is exploited through wells. In the conditions of an increased water demand is imposed a supplementary input from another hydrographic basin. This can be caused by the development of a high water consuming economic activity or by the intensification of punctual irrigations (in greenhouses), the supply of swimming pools etc. the closure of Ostra mine, which represented the only industrial activity in the area, has led to the elimination of a pollution source and as a consequence to the improvement in surface and underground water quality.

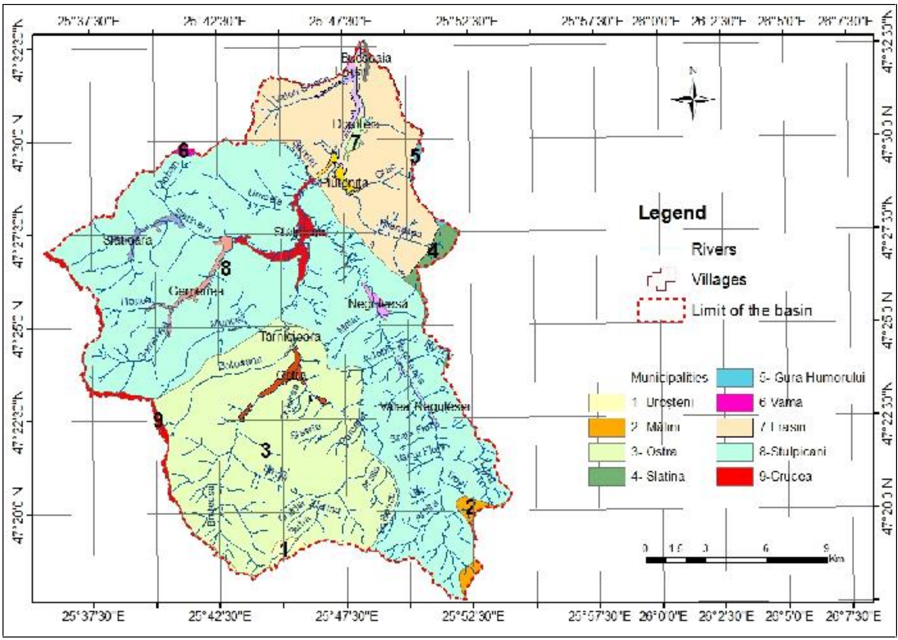

Fig. 4. Distribution of localities in Suha basin with their administrative territories

Over-exploitation remains the only human-induced risk for diminishing water resources in Suha basin, and it can be amplified by the frequent periods of climatic and hydrologic drought.

Conclusions

The analysis of the minimum discharge rates in Suha basin led to the conclusion that water resources are limited. The high water demand is due to the high number of inhabitants in the basin (one of the highest human densities in the Eastern Carpathians). The development of the mining sector at Ostra has attracted an important number of workers during the communist period, who established in the nearby villages. The closing of the mining exploitation from the post-communist period has led to an improvement in water quality, but did not led also to a negative migratory flux. The present reserves of surface water are practically insufficient for satisfying present demands. Because of this reason an intense artisanal exploitation of underground reserves is made through local wells. The higher demands for water from the last years are due to increasing dwelling comfort by using showers, irrigating lawns, supplying pools from guest-houses, cultivating crops in greenhouses. In order to conserve the present underground and surface water reserves is needed to maintain the present forestation degree in the entire basin, installing septic tanks so as avoid underground water pollution, emplacing a reservoir that would provide for the deficit during the minimum discharge period etc.

Acknowledgments

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References

[1] M.F.P. Bierkens, *Global hydrology 2015: State, trends, and directions*, **Water Resources Research, 55**(7), 2015, pp. 4923-4947.

[2] A. Brun, *La politique de l'eau en France (1964-2004). Un bilan discutable*, **Politiques de l'eau. Grands principes et realites locales** (Editors: A. Brun and F. Lasserre), Presses de l'Universite du Quebec, 2006, pp. 17-46.

[3] R.D.H. Bugan, N.Z. Jovanovic, W.P. De Clercq, *The water balance of a seasonal stream in the semi-arid Western Cape (South Africa)*, **Water SA, 38**(2), 2012, pp. 201-212.

[4] W.J. Cosgrove, D.P. Loucks, *Water management: Current and future challenges and research directions*, **Water Resources Research, 51**(6), 2015, pp. 4823-4839.

[5] J.R.M. Hosking, J.R. Wallis, *Some statistics useful in regional frequency analysis*, **Water Resources Research 29**(2), 1993, pp. 271-281.

[6] F. Lasserre, *La gestion de l'eau dans les agglomerations de l'ouest americain. Les autorites locales et regionales privilegient toujours une gestion cloisonnee en attendant la crise,* in: **Politiques de l'eau. Grands principes et realites locales** (Editors: A. Brun and F. Lasserre), Presses de l'Universite du Quebec, 2006, pp. 225-251.

[7] D. Loczy, J. Deszo, S. Czigany, P. Gyenizse, E. Pirkhoffer, A. Halasz, *Rehabilitation potential of the Drava river floodplain in Hungary*, **Water Resources and Wetlands. Conference Proceedings 11-13 September 2014, Tulcea-Romania**, 2014, pp. 21-29.

[8] R.H. McCuen, W.M. Snyder, **Hydrologic Modeling: Statistical Methods and Applications**, Prentice-Hall Englewood Cliffs, NJ., 1986.

[9] J.L. Sabo, E.M. Hagen, *A network theory for resource exchange between rivers and their watersheds*, **Water Resources Research, 48**(4), 2012, pp. W04515. Doi:10.1029/2011WR010703.

[10] L.K. Sherman, *Streamflow from rainfall by the unit-graph method*, **Engineering News Record, 108**, 1932, pp. 501-505.

[11] Z. Srdjevic, B. Srdjevic, *Introducing the social participation concept in water management in Serbia, and related decision making issues,* **Water Resources, 40**(4), 2013, pp. 469-475.

[12] D.G. Tarboton, *A new method for the determination of flow directions and upslope areas in grid digital elevation models,* **Water Resources Research, 33**(2), 1997, pp. 309-319.

[13] C. Teodosiu, G. Barjoveanu, J.V. Kruijf, *Public participation in water resources management in Romania: issues, expectations and actual involvement,* **Environmental Engineering and Management Journal, 12**(5), 2013, pp. 1051-1063.

[14] D. Turnock, *Water Resource Management. Problems in Romania*, **GeoJournal, 3**(6), 1979, pp. 609-622.

[15] A. Tirnovan, G.M. Cojoc, G. Romanescu, F. Obreja, *Predicting the potential index of major floods production in the Suha river basin (Suha Bucovineana)*, **Water Resources and Wetlands, Conference Proceedings, 11-13 September 2014, Tulcea-Romania**, 2014, pp. 539-545.

[16] A. Tirnovan, G. Romanescu, G.M. Cojoc, C. Stoleriu, *Flash floods on a forested and heavily populated catchment. Case study for Suha basin (Romania),* **14th SGEM GeoConference on Water Ressources. Forest, Marine and Ocean Ecosystems, Section Hydrology and Water Resources. Forest, Marine And Ocean Ecosystems, SGEM2014 Conference Proceedings, June 19-25, 2014, 1**, 2014, pp. 303-314. DOI: 10.5593/SGEM2014/B31/S12.040.

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

[18] A. Tirnovan, G. Romanescu, M.G. Cojoc, *Floods and drought - hydroclimatic risk in Suha river basin*, **Air and Water Components of the Environment**, 2014, pp. 188-195.

[19] M.C. Anton, M.M. Baltazar Rojas, A. Aluculesei, R. Marguta, D. Dorohoi, *Study regarding the water pollution in Romania and Spain*, **Romanian Journal of Physics, 53**(1-2), 2008, pp. 157-163.

[20] M.C. Burlacu-Arsene, C. Leonte, M.C. Antonescu, A.V. Sandu, M.G. Minciuna, *Influence of Water Deficit Stress on Some Physio-morphological Indicies at Some Oilseed Rape Cultivars*, **Revista de Chimie, 66**(4), 2015, pp. 487-491.

[21] D. Cirtina, C. Capatina, C.M. Simionescu, *Assessment of Motru and Motru Sec Rivers Quality by Monitoring of Physico-chemical Parameters and Water Quality Index*, **Revista de Chimie, 66**(8), 2015, pp. 1184-1189.

[22] M. Iordache, L.R. Popescu, L.F. Pascu, C. Lehr, E.M. Ungureanu, I. Iordache, *Evaluation of the Quality of Environmental Factors, Soil and Water in the Parang Mountains, Romania*, **Revista de Chimie, 66**(7), 2015, pp. 1009-1014.

[23] I.K. Kouamé, L.K. Kouassi, B. Dibi, K.M. Adou, I.D. Rascanu, G. Romanescu, I. Savané, I. Sandu, *Potential groundwater pollution risks by heavy metals from agricultural soil in Songon area (Abidjan, Côte d'Ivoire)*, **Journal of Environmental Protection, 4**, 2013, pp. 1441-1448.

[24] V. Patroescu, C. Jinescu, C. Cosma, I. Cristea, V. Badescu, C.S. Stefan, *Influence of Ammonium Ions on the Treatment Process Selection of Groundwater Supplies Intended to Human Consumption*, **Revista de Chimie, 66**(4), 2015, pp. 537-541.

[25] L.R. Popescu, M. Iordache, G.O. Buica, E.M. Ungureanu, L.F. Pascu, C. Lehr, *Evolution of groundwater quality in the area of chemical platform*, **Revista de Chimie, 66**(12), 2015, pp. 2060-2064.

[26] G. Romanescu, I. Jora, C. Stoleriu,. *Modification by the River Vaslui of the Hydrological regime and its Economic Implications (Romania)*, **World Academy of Science, Engineering and Technology, 79**, 2013, pp. 1852-1859.

[27] G. Romanescu, M.A. Cretu, I.G. Sandu, E. Paun, I. Sandu, *Chemism of Streams Within the Siret and Prut Drainage Basins: Water Resources and Management*, **Revista de Chimie, 64**(12), 2013, pp. 1416-1421.

[28] G. Romanescu, E. Paun, I. Sandu, I. Jora, E. Panaitescu, O. Machidon, C. Stoleriu, *Quantitative and Qualitative Assessments of Groundwater into the Catchment of Vaslui River*, **Revista de Chimie, 65**(4), 2014, pp. 401-410.

[29] G.Romanescu, I. Sandu, C. Stoleriu, I.G. Sandu, *Water Resources in Romania and Their Quality in the Main Lacustrine Basins*, **Revista de Chimie, 63**(3), 2014, pp. 344-349.

[30] G. Romanescu, A. Tarnovan, I.G. Sandu, G.M. Cojoc, D. Dascalita, I. Sandu, *The Quality of Surface Waters in the Suha Hydrographic Basin (Oriental Carpathian Mountains)*, **Revista de Chimie, 65**(10), 2014, pp. 1168-1171.

[31] G. Romanescu, A. Tirnovan, I. Sandu, G.M. Cojoc, I.G. Breaban, A. Mihu-Pintilie, *Water Chemism Within the Settling Pond of Valea Straja and the Quality of the Suha Water Body (Eastern Carpathians)*, **Revista de Chimie, 66**(10), 2015, pp. 1700-1706.

[32] G. Romanescu, M. Iosub, I. Sandu, I. Minea, A. Enea, D. Dascalita, O.E. Hapciuc, *Spatio-temporal Analysis of the Water Quality of the Ozana River*, **Revista de Chimie, 67**(1), 2016, pp. 42-47.

[33] V. Vasilache, M.A. Cretu, L.F. Pascu, M. Risca, E. Ciornea, C. Maxim, I.G. Sandu, C.I. Ciobanu, *Dehydrogenases activity in sludge samples of Suceava river*, **International Journal of Conservation Science, 6**(1), 2015, pp. 93-98.

[34] M. Amariucai, G. Romanescu, C. Rusu, *Surface hydrical potential and its capitalization in the eastern part of Romania (Moldavia)*, **Buletinul Societatii de Geografie din Romania, Special issue dedicated to the Congress of International Geographical Union „One Earth – Many Worlds", Glasgow, 15-20 August 2004, 10**(80), 2004, pp. 109-123.

[35] A.G. Antonescu, *The management of water resources in Romania*, **Calitatea, 15**(S1), 2014, pp. 503-506.

[36] A. Ciomos, L. Imre, T. Mihailescu, R. Mihailescu, *Perspectives on the Responsible onsumption of the Water Resources in Romania*, **ProEnvironment, 8**, 2015, pp. 606-615.

[37] G.M. Cojoc, A. Tirnovan, G. Romanescu, *Hydrologic forecasting in Bistrita catchment area with the help of RFS program (River Forecasting System) (Romania)*, **Water Resources and Wetlands, Conference Proceedings, 11-13 September 2014, Tulcea-Romania**, 2014, pp. 546-554.

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

[39] F. Corduneanu, D. Bucur, S.M. Campeanu, I.C. Apostol, Al. Strugariu, *Hazards resulting from hydrological extremes in the upstream catchment of the Prut River*, **Water Resources, 43**(1), 2016, pp. 42-47.

[40] D. Dascalita, *Integrated water monitoring system applied by Siret River Basin Administration from Romania, important mechanism for the protection of water resources*, **Present Environment and Sustainable Development, 5**(2), 2011, pp. 45-60.

[41] C. Huma, *Consumul de apa - indicator al calitatii vietii*, **Calitatea vietii, 26**(1), 2015, pp. 67-84.

[42] M. Iosub, I. Iordache, A. Enea, G. Romanescu, I. Minea, *Spatial and temporal analysis of dry/wet conditions in Ozana drainage basin, Romania using the standardized precipitation index*, **International Multidisciplinary Scientific Geoconference SGEM 2015, Water Resources. Forest, Marine and Ocean Ecosystem. Conference Proceedings, 1**, 2015, pp. 585-592.

[43] I. Jora, G. Romanescu, *Influenta activitatilor antropice asupra regimului hidrologic al raului Vaslui, Resursele de apa din Romania*, **Lucrarile primului simpozion national, 11-13 iunie 2010, Targoviste, Editura Transversal, Targoviste**, 2010, pp. 201-208.

[44] D. Lazarescu, I. Panait, **Regimul hidrologic al raurilor**, Ed. Ceres, Bucuresti, 1957.

[45] C. Mociornita, A. Dinca, M. Nitulescu, *Repartitia scurgerii pe sezoane si luni in cadrul anului mediu pe raurile din R. P. R.*, **Studii de hidrologie, 5**, 1963, pp. 3-24.

[46] L. Mustata, *Cercetari privind formarea scurgerii in bazinul reprezentativ Suha*, **Studii de hidrologie, 27**, 1970, pp. 35-63.

[47] G. Pehoiu, O. Murarescu, *Environment and water resources in Targoviste Plain (Romania)*, **Water and Geoscience**, 2010, pp. 90-95.

[48] C. Purice, G. Romanescu, Gabriela Romanescu, *The Protection of the Geomorphosites within the Macin Mountains National Park (Romania) and their Touristic Importance*, **International Journal of Conservation Science, 4**(3), 2013, pp. 373-383.

[49] G. Romanescu, F. Lasserre, *Le potentiel hydraulique et sa mise en valeur en Moldavie Roumaine*, in: **Politiques de l'eau. Grands principes et realites locales** (Editors: A. Brun, F. Lasserre), Presses de l'Universite de Quebec, 2006, pp. 325-346.

[50] G. Romanescu, *Le potentiel hydrique de surface dans les bassins versants des rivières Siret et Prut*, **Lucrarile Seminarului Geografic „Dimitrie Cantemir", 28**, 2008, pp. 13-31.

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

[52] D.C. Diaconu, D. Peptenatu, A.G. Simion, R.D. Pintilii, C.C. Draghici, C. Teodorescu, A. Grecu, A.K. Gruia, A.M. Ilie, *The restrictions imposed upon the urban development by the piezometric level. Case study: Otopeni-Tunari-Corbeanca*, **Urbanism. Architecture. Constructions, 8**(1), 2017, pp. 27-36.

[53] Emm. de Martonne, **Traité de Géographie Physique. Le relief du sol** (tome second), Librairie Armand Colin, Paris, 1926, p. 1057.

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