SOUTH-WESTERN APUSENI MOUNTAINS SMALL RIVERS SEASONAL HYDROLOGICAL FLOW REGIME

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ABSTRACT. – South-Western Apuseni Mountains Small Rivers Seasonal Hydrological Flow Regime. The researched area overlaps the territory belonging to Crişul Alb and Crişul Negru river basins. The study is based on processing and interpretation data from 33 hydrometric stations of which 18 stations control hydrographic basins with surfaces of less than 150 km^2. To highlight the seasonal hydrological flow regime, we took into account three time periods (1950-1967, 1950-2009 and 1970-2009). For all rivers the highest flow values appear during springtime, while the smallest contribution to the multiannual average volume is realized in autumn. The time variation of seasonal flow was highlighted by analysis and variation of extreme values coefficients and also by analysing seasonal flow trends that appeared in all three time periods.

Keywords: seasonal flow regime, Apuseni Mountains, Crişul Alb, Crişul Negru

INTRODUCTION

The analysed area is situated on the eastern part of the watershed that separates the basins of the Someşul Mic (with Căpuş and Someşul Cald rivers), Arieş (with Arieşul Mare and Arieşul Mic rivers) and Ampoi River's, from the basins of Crişul Negru and Crişul Alb rivers (Fig. 1). The two hydrographic systems include a great part of the western (Pădurea Craiului, Bihor and Metaliferi Mountains) and south-western (Zarand and Codru Moma Mountains) mountainous area of the Apuseni Mountains and the transition area to the Beiuş and Zarand depressions as far as to the epigenetic gorge sectors of Petrani – Borz on Crişul Negru River and Joia Mare on Crişul Alb River.

The biggest part of the territory belongs to the asymmetric hydrographic basin of Crişul Negru River, an asymmetric basin with the most important tributaries coming from the right and draining the western slopes of Bihor (Codrişul Băița Stream with Sighiştel, Crişul Pietros River with Galbena and Bogata, and Nimăeşti Stream with Beuşele) and Pădurea Craiului Mountains (Valea Roşie River with Sohodol, Şoimuş and Meziad). From the left side, Crişul Negru River receives smaller tributaries, mostly from the Codru Moma Mountains (Țarinii, Brihenilor, Valea Mare, Tărcăița, Finiş and Arman streams).

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The only tributary from the left river side arriving from the southern slopes of Bihor Mountains is Crıştior Stream.

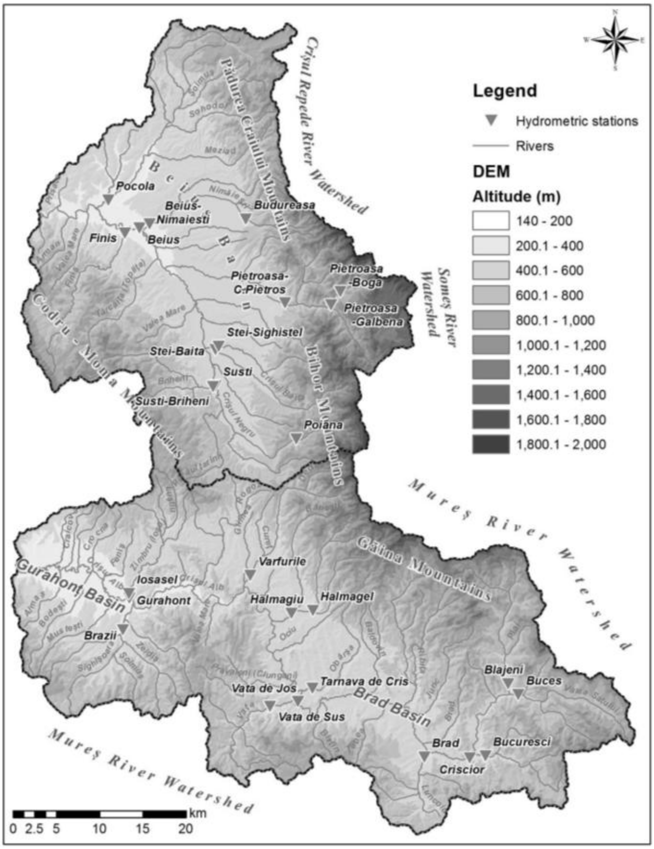


Fig.1. ***Rivers network and hydrometric stations distribution in south-western Apuseni Mountains***

The Crişul Alb River drains a smaller surface with altitudes generally between 300 and 600 m, so 1400-1500 m can be found only on the southern slopes of Bihor Mountains where is the spring of the Crişul Alb River (below the Certezul Peak – 1184 m).

This river gets out of the mountainous area at Blăjeni, receiving downstream of this point Valea Satului Stream and some tributaries from the Metaliferi (Bucureşci and Luncoiu streams) and Zarandului Mountains (Vața, Sighişoara or Zeldiş, Muteşti and Almaş streams).

Most tributaries of Crişul Alb River come from the right river side. So, from the southern slopes of Bihor Mountains come some small tributaries (Artan, Brad and Juncu streams), followed by some high water flow streams (Baldovinul, Şteiul or Obârşia, Ociul, Valea Hălmagiului, Valea de la Iazuri streams) – this is explained by the basins favourable exposure towards the western and south - western air masses advection.

The tributaries coming from the southern slopes of Codru Moma Mountains are represented by Aciuței Stream (or Tăcăşele), followed by Gruiețu, Valea Ioşei, Fenişu, Crocna, Poloşanca, Craicova and Topoşa streams (Fig.1).

The individuality of the studied geographic area is underlined by some characteristic features: orientation of water flow direction from east to west; succession of narrow sectors with broad sectors due to geological alternation; high frequency of western oceanic air masses and south-western wet subtropical air masses during winter time; high rainfall volume due to the rainfall reactivation by orographic convection and compression processes in the areas with narrow depressions.

The territorial differentiations are imposed by the relief's altitude and orientation, which allowed the individualization of two areas with distinct geographical features, a mountainous and a depressionary area.

The *mountainous area* includes the high space corresponding to the region situated at the eastern extremity of Bihor and Pădurea Craiului Mountains, which represent an orographic barrier in the way of western moist air masses. In the region's south-western part, corresponding to Zarand and Codru Moma Mountains can be observed a general altitude decrease from east to west.

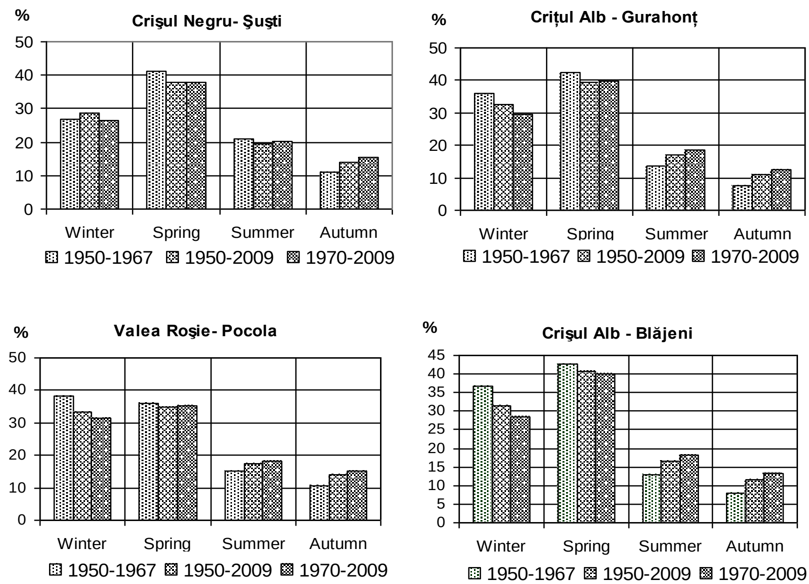


Fig. 2. ***Seasonal flow percentage values***

The *depressionary area*, lower and well humanized, appears in the form of well evidenced basin along the Crişul Alb River. It shows different morphologic and morphometric characteristics because it's different geneses, is also separated by volcanic hills, which are cut by the river into narrow gorges, including the one between Gurahonț and Grid that enabled the subdivision into two distinct sections. In the east appears the Brad inner mountain Depression and in west the Zarand Depression. The two areas present a series of well individualised basins, usually separate by the epigenetic sectors of Crişul Alb valley. Thus, the small gorge between Birtin and Vața separates Brad Basin from Hălmagiu Basin, while the Joia Mare gorge separates the Gurahonț Basin from the Zarand Depression.

The two areas present a series of well individualised basins, separated by epigenetic sectors of the Crişul Alb valley. Thus, the small gorge between Birtin and Vața separates Brad Basin from Hălmagiu Basin, while the Joia Mare gorge separates the Gurahonț Basin from the Zarand Depression.

2. DATA BASE AND METHODS

For this study there were taken into consideration three periods: a long one (1950-2009) and two shorter ones (1950-1967 and 1970-2009). The last allowed using data from 33 hydrometric stations, of which 18 control hydrographic basins with less than 150 km^2 areas.

After analysing the seasonal flow percentage contribution to the annual average flow volume in all three periods, some aspects can be observed. Thus, the rivers from Crişul Alb Basin and the tributaries of Crişul Negru River coming from Pădurea Craiului Mountains present winter flow percentage values that slowly decreased during the last two periods corresponding to the interval 1950-1967.

Compared to the period 1950-1967, the autumn flow percentage values have permanently increased during the periods 1950-2009 and 1970-2009 (Fig.2). In all rivers, the spring flow percentage values from the three analyzed periods remained significantly close.

For evaluation of the main parameters (duration, frequency, variability, average and extreme values) we used statistical methods that allowed the identification of some central trends in the parameters variability. The relations between the above parameters were highlighted using correlation matrices.

3. RESULTS AND DISCUTIONS

The interpretation of the results obtained after the statistic processing of the data allowed us to identify particularities in the seasonal river flow repartition of the studied area. Using data for the period 1970-2009 and the correlation between seasonal flow values and the catchments average altitude, the results showed that the seasonal river flow repartition in the studied region is strongly connected with the climatic conditions; the influence of other physical-geographical factors produces local differentiations.

3.1. Seasonal flow spatial variation

During winter time (XII - II), the flow's spatial repartition is highly influenced by the fallen rainfalls quantity (rarely in liquid form) and the thermic regime. The negative air values preserve the snow, causing rivers to frost, and eliminate large quantity of water from the water circuit. But at the same time, the western and south- western climatic influences, expressed by the intercalation of some positive temperatures and liquid precipitations periods, are more frequent and longer in this area than on the eastern slopes of Apuseni Mountains. As a result, the territorial differences of seasonal flow percentage values are determined by the average altitude of drainage basins and their exposure to the western and south-western air masses advection. Thus, the lowest percentage values of winter flow (over 30% from the annual average volume) appears on the rivers from Crişul Alb basin, upstream Vața de Jos, draining the Metaliferi Mountains (Valea Satului, Bucuresci, Luncoiu and Vața). Low average altitude values for the river basins mentioned above (between 450 – 650 m) and favourable exposure to south-western air masses advection determine high percentage values for winter flow.

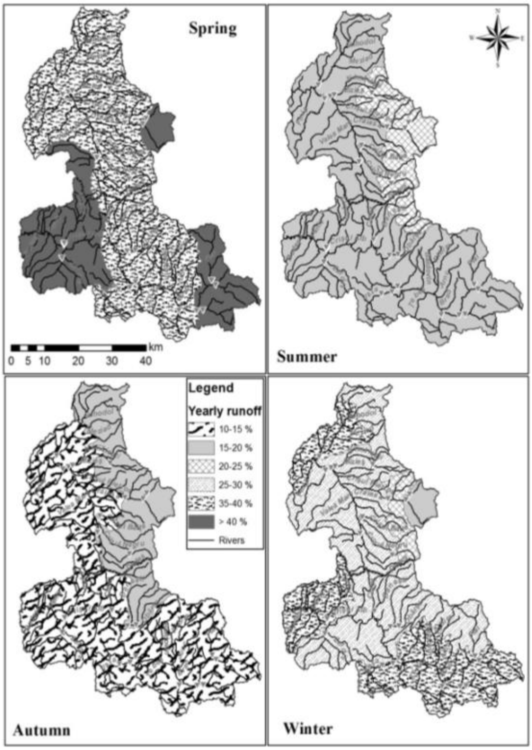


Fig. 3. ***Space repartition of seasonal flow percentage values***

High winter flow values (above 30%) appear also in the western areas of Crişul Alb and Crişul Negru basins, drained by the tributaries of these two rivers that reach the main rivers downstream Gurahonț (Valea Ioşei, Crocna, Poloşanca, Craicova and Topoşa), respectively Beiuş (Valea Roşie, Finiş and Arman). Low average altitude values (300 – 500 m) of drainage basins and their exposure to western air masses advection increase frequent intercalation of positive temperatures and liquid precipitations periods.

Medium winter flow percentage values (25 – 30%) appear on the rivers draining a large surface from our study area (Fig. 3). In this category are included the right tributaries of Crişul Alb coming from the southern slopes of Bihor Mountains that present a favourable exposure to south – west air masses advection (Ujvari, 1972) and the left tributaries that reach the river between Vața de Jos and Gurahonț (Fig. 3).

An area corresponding to same flow values (25-30% from the annual flow volume) appears on the northern slopes of Codru Moma and Pădurea Craiului Mountains, and also in the Beiuş Depression downstream Şuşti (Fig. 3).

Once the relief's altitude increases, the winter flow percentage values decrease, with below 20% of the annual flow volume (Fig. 2). Such situations appear on the rivers from the high altitude area of Bihor Mountains (above 1400 m), where the high frequency of negative temperatures reduce the possibility of water alimentation from snow sources.

The spring (III - V) represents the season with the highest flow values determined by snow melting, relatively high rainfall quantity and low evapotranspiration values and low water infiltration into a soil that's oversaturated or partially frozen. During this season, the average flow volume is high, representing 35,2 % % (Valea Roşie at Pocola) and 40.9 % (Valea Satului at Buceş) from the annual average volume.

The highest spring flow percentage values (40-41%) appear on the rivers from upper Crişul Alb and Pietroasa drainage basins (Boga and Galbena) and on the tributaries from downstream Vața de Jos. They also appear on the tributaries of Crişul Negru River from the high altitude area of Codru Moma Mountains (Briheni).

On the biggest part of the studied area, the spring flow percentage values remain between 35 and 40%.

During summer time (VI - VIII), the rainfalls quantity decrease, the air temperature increase and the development of vegetal carpet contribute to evapotranspiration intensification, triggering the intense flow decrease towards the previous season. During summer time 17,1% (Bucuresci Stream at Bucureşci) and 22,7 % (Boga Stream at Pietroasa) happens from the annual average flow. The lowest summer flow values (between 15 and 20% from the annual average volume) appear on most rivers from Crişul Alb Basin and on the left tributaries of Crişul Negru River, those rivers that come from Bihor Mountains and on some tributaries of Crişul Alb River that come from the same mountains (Hămăgel and Hălmagiu).

During autumn (IX - XI), the evaporation decreases and the underground water reserves are drained. As so, at the beginning of this season a period with low waters appears, and at the end of it, a period with floods generated by persistent rainfalls. Autumn is the season with the lowest contribution to the annual average volume (10,9% at Bucuresci on Bucuresci Stream and at Brazi on Sighişoara Stream). The autumn flow percentage values maintains between 11 and 15% on the most part of Crişul Alb Basin and on the left tributaries of Crişul Negru (Fig. 3).

Higher autumn flow values (between 15 and 20%) appear especially on the tributaries of Crişul Negru River coming from Pădurea Craiului and Bihor Mountains. In this case, it can be observed a decrease of flow values from north towards south.

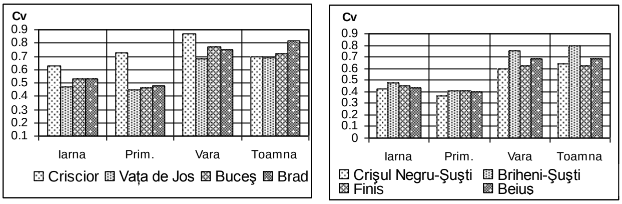
3.2. Seasonal flow types

These types were determined according to season's succession in decreasing order due to their contribution to the annual flow, excepting spring time, which is the predominant season for all rivers in our study area. It can be observed, as a contrast with the rivers from the eastern slope of Apuseni Mountains, that at the rivers from our study area is predominant the type W.S.A., with the highest seasonal flow, after that during spring, happening in winter, and the lowest in autumn. The exceptions are the rivers with their origin in the high altitude area of Bihor Mountains (Pietroasa Stream), with the type S.W.A., which appears also on the rivers from Arieşul Mare and Arieşul Mic river basins (Sorocovschi et al., 2013).

3.3. Seasonal flow oscillations and trends

The flow variation in time was highlighted using variation coefficients. During spring and winter, the lower values of this parameter show a more uniform time distribution for seasonal flow. But during summer and autumn, the variation coefficients values are the highest.

Variation coefficient values depend on basin’s area, because the higher the surface, the more can be felt the runoff’s regularizing characteristic. For basins with similar average altitudes, the humidity has a determinant role.



a **b**

Fig. 4. ***Seasonal variation coefficients values at the hydrometric stations from Crişul Alb (a) and Crişul Negru basins (b)***

Table 1. ***Linear trends of seasonal flow****

River	**Hydrometric station**	**Winter**	**Spring**	**Summer**	**Autumn**
Crişul Alb	Blăjeni	S.D.	ST.	A.D.	S.D.
Crişul Alb	Criscior	S.D.	S.D.	A.D.	S.D.
Crişul Alb	Vaţa de Jos	ST.	S.I.	A.D.	ST.
Crişul Alb	Gurahonţ	ST.	S.I.	A.D.	ST.
Valea Satului	Buceş	S.D.	ST.	A.D.	ST.
Bucuresci	Bucuresci	ST.	S.I.	A.D.	ST.
Luncoiu	Brad	S.D.	ST	A.D.	ST.
Vaţa	Vaţa de Sus	A.D.	ST.	A.D.	ST.
Băneştilor	Hălmagiu	S.D.	S.D.	A.D.	ST.
Hălmăgel	Hălmăgel	A.D.	A.D.	A.D.	S.D.
Valea de la Lazuri	Vârfurile	ST.	ST.	A.D.	ST.
Sighişoara	Brazi	S.I.	S.I.	A.D.	ST.
Ioşei	Iosăşel	ST.	S.I.	S.D.	ST.
Crişul Negru	Şuşti	ST.	S.I.	A.D.	ST.
Crişul Negru	Beiuş	ST.	S.I.	A.D.	S.I.
Briheni	Şuşti	ST	S.I.	A.D.	ST.
Boga	Pietroasa	A.D.	A.D.	A.D.	S.D.
Finiş	Finiş	ST.	S.I.	A.D.	ST.
Valea Roşie	Pocola	S.I.	A.I.	A.D.	S.I.

S.D. – slight decrease; A.D. – accentuated decrease; S.I. – slight increase; A.I. – accentuated increase; St. - stationary

This is the case for two hydrometric stations – Buceş and Şusti on Briheni Stream. The trend of seasonal flow evolution between 1970 – 2009 present a great areal variety, being determined more by natural factors (especially climatic) than anthropic ones. At most hydrometric stations, the winter flow presents a slightly decreasing or stationary trend. The slight increasing trend of winter flow appeared on Valea Roşie and Sighişoara streams (Table 1).

During spring time, the flow trend presents differences, with a slight increase on Crişul Alb River and Bucuresci and Sighişoara streams, and an accentuated increase on Valea Roşie Stream. Stationary flow trends appear on Valea Satului, Luncoi, Vaţa and Valea de la Lazuri streams. A slight decreasing trend of spring flow appeared on Crişul Alb River at Criscior and on Băneşti Stream, and accentuated decrease on Hămăgel and Boga streams. In summer, all rivers present a decreasing flow trend. In autumn, most rivers present a stationary or a slightly decreasing trend (Table 1). A slight increasing flow trend appeared in a few cases (Valea Roşie Stream at Pocola and Crişul Negru River at Beiuş).

CONCLUSIONS

Our study area presents a big diversity of flow's genetic factors. As a result, seasonal flow regime characteristics have a very different behaviour in space, determining areas with specific characteristics imposed by natural factors, but also by anthropic ones.

The space repartition of seasonal flow shows some differences especially during winter time, when the altitude and the exposure to western and southern air masses advection represent determinant factors, and all the other natural factors have only an influencing role. The analysis of these factors correlated with the flow regime particularities allowed us to identify areas with different flow regime behaviour.

About the time variation of seasonal flow, it can be observed an accentuated decreasing flow trend during summer time and a predominant stationary trend during autumn.

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