THE PECULIARITIES OF SEASONAL FLOW REGIME ON SMALL RIVERS FROM THE EASTERN APUSENI MOUNTAINS

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ABSTRACT. The Peculiarities of Seasonal Flow Regime on Small Rivers from the Eastern Apuseni Mountains. Investigated region is overlapping the territory drained by tributaries of Someşul Mic and Arieş River and also the creeks collected by Mureş River between the mouth of Arieş and Geoagiu River. The study is based on processing and interpreting data from 24 gauging stations, of which 18 control surfaces basins below 150 km^2. To highlight the features of seasonal flow regime we have considered three periods (1950-1967, 1950-2009 and 1970-2009). Thus, all rivers are recording a dominant flow during spring while the lowest annual average volume is related to winter season. Seasonal time variation of river flow was highlighted by analyzing the trends in the three periods using the variation coefficients.

Keywords: flow regime, runoff spatial variation, Apuseni Mountains

1. INTRODUCTION

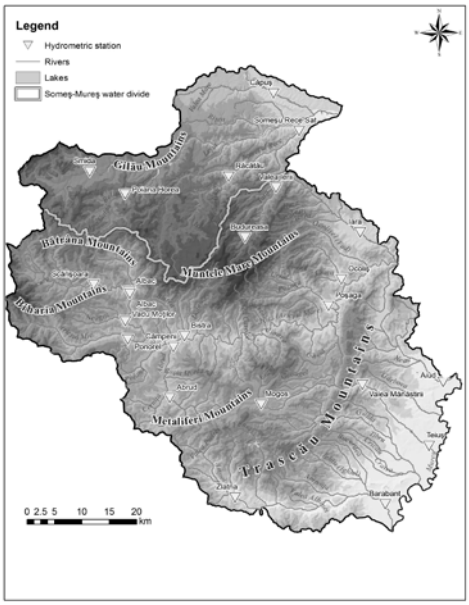

Fig. 1 The main relief units

The studied area is located east of the line of greatest heights, which separates Someşul Mic tributaries (Căpuşul and Someşul Cald), Arieş tributaries (Arieşul Mare and Arieşul Mic), those of Ampoiului River, and those collected by Crişuri Rivers (Fig. 1). The individuality of studied geographic area is highlighted by several characteristic features like: water flow direction from west to east, the sequence of narrow and broadening sectors due to geological alternation; a frequent *foehn* process which contributes to the individualization of a local climate with lower values of cloudiness and precipitation and with average annual temperatures higher than sites located at similar altitudes in Western Apuseni Mountains (Arghiuş V., Arghiuş Corina, 2004); the high degree of humanization.

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Territorial differentiations imposed by terrain elevation, have allowed the individualization of two areas with distinct geographical features. *The Mountain area,* which includes the high region (with altitudes from 1500-1800 m), corresponding to the region of Vlădeasa and Bihor mountains, which is an orographic barrier in the way of wet air masses from the west.

In the northern and central mountain region the altitude increases from the Gilău Mountains (1475 m) to Muntele Mare Massif (1500-1800 m), where there is a prominent general reduction of altitude from west to east. The mountain area of southern and eastern part of studied region belongs to the Metaliferi Mountains and Trascău Ridge with lower altitudes (1200 - 1400 m).

The lowland area, well humanized, is represented by the several small basins situated along Arieşul Mare River (Arieşeni, Gârda and Albac), Arieşul Mic River (Avram Iancu, Vidra), Arieş River (Câmpeni, Bistra, Lupşa, Baia de Arieş, Sălciua), Ampoi creek (Zlatna) and some tributaries of Arieş (Ocoliş, Poşaga, Iara, Remetea). The depression basins along Someşul Cald River are currently occupied by the waters of Fântânele and Someşul Cald reservoirs.

2. DATABASE

For the study analysis we have considered three periods: one long (1950-2009) and two shorter (1950-1967 and 1970-2009). Last period enabled the data capitalization from a representative number of 24 gauging stations. From the analysis of seasonal runoff percentage, for the achievement of average annual volume of the three periods, we have noted that during the 1950-2009 winter flow percentage values remained higher while the flow of autumn are reduced compared to other periods (Fig. 2). Spring runoff percentage values of the three periods analyzed remained significantly close on Arieşul Mare River and Iara creek and higher on the Răcătăului and Ampoiului basins. The percentage values of summer flow in the period 1950-2009 are slightly reduced compared to those for the last two periods (Fig. 2).

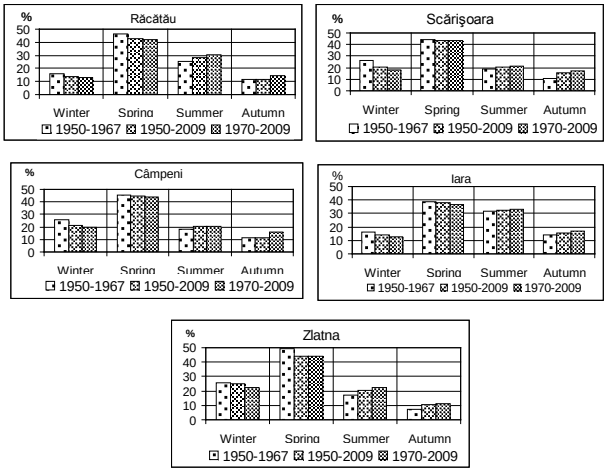

Fig. 2. Percentage values of flow in the considered three periods

3. THE SEASONAL RUNOFF REGIME

The analysis of data processed for the period 1970-2009 and the correlation made between the percentage values of seasonal flow and average altitude of catchments have showed that the seasonal flow of rivers in the studied region is closely related to climatic conditions. The influence of other physical-geographical factors can induce several patterns with local character.

3.1. Patterns of spatial – temporal seasonal runoff

In *winter (month XII - II)* territorial distribution of runoff is influenced largely, beyond the amounts of rainfall (less liquid) by the thermal regime. Negative air temperatures are allowing a state of conservation for the snow cover, ensure the frost process in rivers and get out of the circuit a large amount of liquid water. At the same time western and southwestern climate influences, manifested by interleaving periods with positive temperatures and liquid precipitation are much reduced compared to the westerns side of the Apuseni Mountains. As a result, regional differences in seasonal flow values are determined by altitude and exposure of catchment basins against the advection of air masses from the west and southwest. The lowest winter runoff in percentage (10-15 % of the annual average) is recorded on the rivers that drain the area of Muntele Mare Massif (Someşul Rece and Iara, in the north, Valea Mare, Poşaga and Ocoliş creeks in the south). High average altitude of mentioned river catchments, (between 1100 and 1359 m), determines the high frequency of negative temperatures, which diminishes the possibilities of rivers feeding through snow melt.

Intermediate values of winter runoff, representing between 16 and 20% of the average annual volume, are recorded on the streams from the Căpuşului, Arieşul Mare (except Neagra River) and Aiudului catchments. Higher percentage values of winter runoff are explained on one hand by the lower elevation catchments of Aiud and Căpuş rivers, while on the other hand by the rich underground sources of the streams from Arieşul Mare catchment.

High percentage values of winter runoff (20-25% of the annual average volume) are recorded on Abrud creek and on rivers that drain mountainous area in southeastern part of the region, with favorable exposure to the advection of air masses from the west (Geoagiu and Ampoi).

From the winter runoff profile variation can be noticed that the highest values of flow were made in different winters: 1995/1996 on the rivers with source in the highland (altitude above 1600 m) of Bihor Mountains (Beliş, Someşul Cald) and of Muntele Mare Massif (Someşul Rece, Iara and Valea Mare) 1978/1979 on Arieşul Mare, Arieşul Mic, Abrud Geoagiu and Căpuş rivers; 1981/1982 on Ocoliş, Poşaga and Ampoi streams. In mentioned winters, climatic conditions were favored the feeding of streams from precipitation, especially from successive melting snow phases. Similar situations occurred in winter 1969/1970 in Aiudului basin and the middle and lower sectors of Iara river.

On most rivers, the lowest values of the flow occurred in winter 1983/1984, characterized by a persistent anticyclonic regime with low amounts of rainfall and low temperatures, which made the most of the river water to be stored in solid state. Similar situations occurred in the winters: 1992/1993 in the Ampoi river basins, Aiud, Geoagiu, Ocoliş, Poşaga, Beliş and Upper Someşul Cald river basins; 2000/2001 winter on Ocoliş and Poşaga streams, and 1986/1987 winter on Beliş and Someşul Cald rivers.

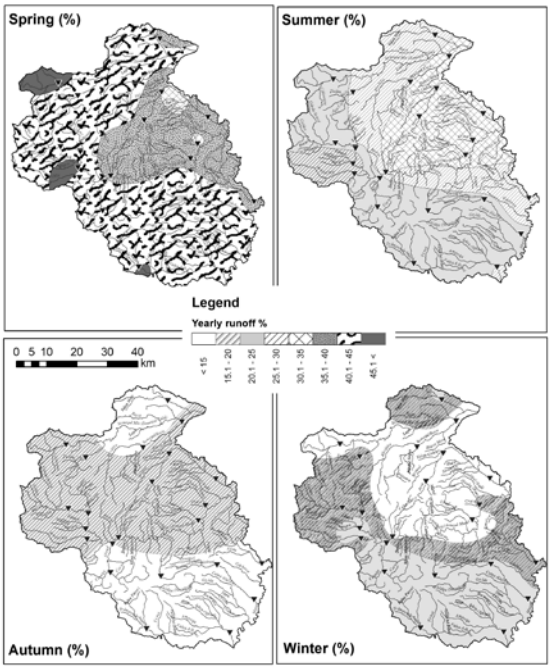

Fig. 3. Spatial repartition of the seasonal runoff (%)

Spring (months III - V) is the richest runoff season (Fig. 3), influenced by snowmelt, high amounts of precipitation and low evapotranspiration and infiltration values in saturated or partially frozen soil. In this season the average volume of runoff is high, representing 38.4 % (Aiud creek at Aiud station) and 45.4% (Someşul Cald at the Smida and Neagra Creek at Vadul Moţilor) of the average annual volume.

Higher percentage values of the spring runoff are associated to the rivers in the upper basin of Arieş (43-45 %) and those from the Metaliferi and Trascău Mountains (42-43 %). The different patterns are dictated by differences in altitude and exposure of the catchments in the two regions. The lowest percentage values (34.8 % and 40 %) were recorded on rivers from Muntele Mare Massif, where the effect of cathabatic circulation is felt and also on Aiud River.

The richest spring runoff has occurred on most rivers in 1970, 2005 and 2006 (Table 1). In the mentioned years, the strong melting snow process and long rains of frontal origin with a fairly high intensity have generated large volumes of water, which flowed at a rate of 80-85 % due to the high humidity content of the substrate layer.

The lowest values of spring runoff occurred in different years: 1973 in the upper basin of Arieş, 1992 on Bistra and Poşaga creeks (table 1) or in two consecutive years (2002 and 2003 on Abrud and Ocoliş streams).

In the *summer* (months VI - VIII) the decrease of precipitation amounts, the increase of temperatures and vegetation development lead to the intensification of

evapotranspiration, resulting in a significant decrease in flow relative to the previous season (spring).

The values recorded in the summer are between 15.7 % (at Vadu Moţilor gauging station) and 34.2 % (on Iara River at Valea Ierii station) of the average annual flow. The lowest values of summer runoff (between 15 and 20 % of the annual volume) are recorded in the basin of Arieşul Mic. Percentage values of summer flow between 21 % and 15 % are typical for rivers from Arieş basin upstream of Câmpeni and for those from the southeastern part of Apuseni Mountains. The largest percentage values of summer flow (31-35 %), close to those of spring runoff, are found on rivers that drain the northern and eastern part of the Muntele Mare Massif.

Table 1. Data regarding the seasonal runoff

Gauging stations	WINTER			SPRING			SUMMER			AUTUMN		
	Cv	Year with flow		Cv	Year with flow		Cv	Year with flow		Cv	Year with flow	
		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.
Căpuş	0.7	1979	1991	0.54	1970	1990	0.95	1979	1991	0.81	1972	1990
Poiana Horea	0.54	1996	1987	0.31	1970	1992	0.4	1996	1987	0.46	2002	2000
Smida	0.5	1996	1987	0.38	2006	1973	0.4	1996	1987	0.58	1998	1983
Răcătău	0.76	1971	1984	0.73	2006	1992	0.99	1971	1984	0.92	1972	1990
Someşu Rece Sat	0.51	1996	1987	0.33	1970	2003	0.45	1996	1987	0.46	1979	1990
Ponorel	0.42	1979	1984	0.36	1970	1973	0.54	1974	2003	0.53	2002	1983
Albac	0.42	1979	1984	0.38	2006	1973	0.41	2006	1993	0.42	2002	1987
Abrud	0.50	1979	1984	0.44	2005	2002	0.58	1975	2000	0.62	1972	2000
Câmpeni	0.48	1979	1984	0.44	2006	2002	0.59	1975	2000	0.67	1996	2000
Bistra	0.41	1996	1984	0.28	2006	1992	0.33	1980	1983	0.36	1998	1983
Ocoliş	0.40	1982	2001	0.40	2005	2002	0.57	2005	2000	0.38	1972	2000
Poşaga	0.34	1982	2001	0.29	2005	1992	0.37	2005	2000	0.32	1972	2000
Budureasa	0.40	1996	1980	0.39	1970	1979	0.43	1973	1993	0.45	1972	1979
Valea Ierii	0.81	1971	1984	0.95	1970	2003	0.95	2005	1994	0.98	1972	2000
Iara	0.73	1970	1984	0.92	1970	1994	0.98	2005	1994	0.81	1972	1983
Mogoş	0.52	1979	1984	0.40	1970	1990	0.59	1975	2007	0.67	1972	2000
V.Mânăstirii	0.51	1979	1984	0.37	1970	2002	0.63	1975	2000	0.62	1972	1987
Teiuş	0.48	1979	1993	0.44	2005	2002	0.65	1975	2000	0.60	1972	2000
Aiud	0.59	1970	1993	0.72	1970	2009	1.24	2005	1993	0.73	1972	1993
Zlatna	0.59	1982	1984	0,51	2006	1972	0,79	1970	2009	0.94	2001	1983
Bărăbanţ	0.50	1982	1993	0.47	2006	2002	1.07	1975	1992	0.66	1972	1987

Compared to the average shown situation, some extreme cases have been reported. The highest summer runoff occurred in different years: 1974 and 2006 on the rivers in the upper basin of Arieş, in 1975 on the south-eastern region, and in 2005 on Muntele Mare Massif (Table 1). The lowest values of summer flow occurred in 2000 and 1993 on the rivers in the upper basin of Arieş, in 2000 on Abrud River, in 1992, 1993 and 1994, on some tributaries of Arieş River.

In *autumn* (months IX - XI), evaporation decreases and underground water deposits are exhausted and unrestored. As a result, at the beginning of the season we have noticed the appearance of low water levels period, while in the final part of the season floods can occur as a result of possible persistent rains. Autumn, is the season with the lowest average annual contribution to the volume (11.2% on

Ampoi river at Zlatna and 19.1% on Iara at Valea Ierii station). The percentage values of autumn runoff remain between 11 and 15% in Răcătăului catchment and on rivers from Metaliferi Mountains; 15.1 and 17% in the upper basins of Someşul Mic (Beliş, Someşul Cald) and Arieş river (except Scărişoara station) 17.1 to 19% on rivers from Muntele Mare Massif. On most rivers the richest autumn flow occurred in 1972, and the lowest in 1983 and 2000 (Table 1).

3.2. Types of seasonal distribution of runoff

The types of seasonal distribution of runoff were established in the succession of the seasons, in decreasing order of contribution to annual flow, except for the spring season, which is predominant in all the rivers of the studied region. It has been found that the dominant *type V.T.I.* is specific to rivers in the upper basin of Someşul Mic (Beliş, Someşul Cald and Someşul Rece) and those that drain the Muntele Mare Massif. *Type V.I.T.* is specific to river basins of Arieşul Mare and Arieşul Mic and those in the Gilău Mountains (Căpuş) and Metaliferi Mountains (Geoagiu and Aiud), which drains areas with altitudes between 600 and 1000 m with favorable position for the advection of air masses from the west. A special type, *I.V.T.* is met on Neagra creek (Vadu Moţilor gauging station) Abrud (at Câmpeni) and Geoagiu creek (at Mogoş), where the highest seasonal flow, after the spring season, occurs in winter and lowest in autumn. In some rivers there is a transformation of the seasonal regime type. Thus, the upper Abrud river fall into *V.I.T.* type while the lower part, at Câmpeni, belongs to the *I.V.T.* type. Ampoiul River at Zlatna is included in *I.V.T. type* and at Bărăbanţ gauging station is undergoing to *V.I.T.* type. Similar situations are found in Geoagiu basin. Identification of this type is explained by differentiated regime of tributaries, which although small, can influence the flow distribution of collector.

3.3. Oscillation and seasonal runoff trend

Variation in time of the flow has been observed with coefficients variation. In spring and winter, lower values of this parameter reflect the uniform flow distribution. Instead, in the summer and autumn, when the coefficients of variation were at the highest values, regional differences are more obviously. Thus, some strong obvious contrasts occur between rivers in the western, southern and the eastern part of the Muntele Mare Massif (Valea Mare, Ocoliş, Poşaga and Iara) and those from the upper basin of Arieş (Arieşul Mare and Arieşul Mic). An intermediate situation presents the rivers that drain the Metaliferi Mountains and rivers that drain Trascău Ridge (Fig. 4).

The meaning of seasonal runoff evolution during 1970 - 2009 shows a territorial diversity, driven by natural factors (especially climate) and anthropogenic. In winter on most rivers, can be noticed a stationary nature of the flow.

The tendency of slight increase in winter runoff was determined on Someşul Cald and Albac and also on Ampoi river at Zlatna station, where is quite pronounced.

Slight decrease trend of runoff is manifested on Arieşul Mic and Abrud, while a strong trend is noticed on Iara river at Valea Ierii gauging station (Table 2).

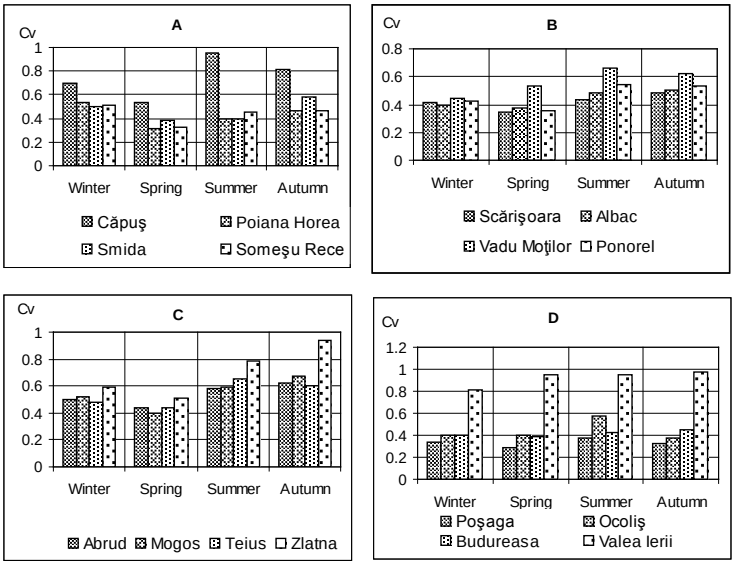

Fig. 4. The seasonal variation coefficients values at the gauging station from Someşul Mic (A) Upper Arieş (B) Metaliferi Mts. (C) and Muntele Mare Massif (D)

Table 2. Linear trends of seasonal runoff

Stream / Creek	Gauging station	Winter	Spring	Summer	Autumn
Căpuş	Căpuş	St.	St.	Du	St
Beliş	Poiana Horea	St.	St	Du	St
Someşu Cald	Smida	Cu.	Cu.	St.	Ca
Răcătău	Răcătău	St.	Su	Sa	Su
Someşu Rece	Someşu Rece Sat	St.	Su	Sa	su
Ariesu Mic	Ponorel	Su	St.	Sa	Cu
Albac	Albac	Cu	St	Su	St
Abrud	Abrud	Su	Cu	Su	St
Abrud	Câmpeni	St	Cu	Su	St
Valea Mare	Bistra	Cu	Cu	St	Cu
Ocoliş	Ocoliş	Su	St	St	Su
Poşaga	Poşaga	St	Cu	St	St
Iara	Budureasa	St	Su	Su	St
Iara	Valea Ierii	Sa	Sa	Sa	Sa
Geoagiu	Mogoş	St	Su	Sa	St
Geoagiu	Valea Mănăstirii	St	St	Su	St
Geoagiu	Teiuş	St	St	Su	St
Aiud	Aiud	St	St	Cu	St
Ampoi	Zlatna	Ca	Ca	St	Cu
Ampoi	Bărăbanţ	St	Ca	St	Su

Legend: St – stationary trend; Cu – slightly increase trend; Ca – strong increase trend; Su – slightly decrease trend; Sa – strong decrease trend

In spring, stationary nature of the runoff has been observed on Căpuş, Beliş, Arieşul Mic, Albac, Ocoliş and on the middle and lower parts of Geoagiu river. Slight increases of spring runoff were noticed on Someşul Cald, Abrud, Valea Mare and Poşaga, while a strong rise of flow was marked on the middle and lower sector of Ampoi River. In the valley of Someşul Rece and the upper Iara, spring runoff trend was slightly downward and sharp at Valea Ierii station. In the summer the flow trend evolution, in the analyzed period, was for the most rivers in a mild decrease (Someşul Rece, Arieşul Mic, upper sectors of Geoagiu and Iara rivers.

In autumn, the spill trend was stationary on Căpuş, Beliş, Albac, Abrud, Poşaga in the upper basin of Iara, and the upper and middle part of Ampoi river. We have noticed a strong growth in the autumn flow on Someşul Cald and a sharp decrease in runoff on Iara River at Valea Ierii hydrometric station (table 2).

4. CONCLUSIONS

The studied region is an area with a great diversity of genetic factors of river runoff. As a result, seasonal flow regime peculiarities are manifested very differently in the area. Thus, we were able to delineate several areas with specific features, primarily conditioned by natural factors, but also by anthropogenic. Their analysis, in conjunction with the particular flow regime, allowed the identification of several areas where runoff regime manifests differently. Thus, we can separate the basin of Arieşul Mare of those of Arieşul Mic and and Abrud rivers; also the upper basins of Someşul Mic against Iara catchment. There are fairly obvious contrasts between the rivers catchments developed in the southern and northern side respectively on western and eastern part of Muntele Mare Massif.

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