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SEASONAL AND MONTHLY FLOW REGIME PARTICULARITIES FOR THE EASTERN APUSENI MOUNTAINS SMALL RIVERS

Victor Sorocovschi, Gavril Pandi, Csaba Horvath, Răzvan Bătinaş
Babeş-Bolyai University, Faculty of Geography, 400006 Cluj-Napoca, Romania, 040264596116
Email s.victor@geografie.ubbcluj.ro, pandi@geografie.ubbcluj.ro,hcs1000@yahoo.com. r.batinas@geografie.ubbcluj.ro

Abstract

The region in study overlays on the territory between Arieş and Geoagiu drained by Someşului Mic, Arieş and Geoagiu rivers tributaries. This study is based on the data processing and interpretation from 24 hydrometric stations, 18 controlling hydrographic basins with surfaces smaller than 180 km^2 and that reflect as well as possible the local particularities of rivers' hydrological regime. To underline the particularities of seasonal flow regime there were taken into account three different periods (1950-1967, 1950-2009 and 1970-2009). The particularities of the geographical land cover from the eastern Apuseni Mountains, especially the climatic and geomorphological ones, reflect themselves very well in rivers' flow regime. On all rivers, the dominant flow is that from springtime, the smallest part in the multiannual flow is brought by the winter flow. There were highlighted the particularities of the three seasonal flow sub-regimes and the areas of specific evolution. The repartition and frequency of the average flow in the months with the highest (March, April and May) and smallest (January, February, August and September) flow values varies very much according to the rivers' drainage basin altitude. The seasonal and monthly flow variation over the years was highlighted using variation coefficients. There were also determined flow trends for the three study time periods. The results of this study show the fact that hydrological regime's rhythmical structure reflects the local characteristics of supply sources, of geological conditions and of relief's morphological and morphometric conditions,.

Keywords: regime, seasonal, monthly**,** type, sub-type, Apuseni Mountains

1. INTRODUCTION

2.

The study area is situated east of the watershed separating Someşul Mic, Arieş and Ampoi river basins from the basins of the Criş rivers (Fig. 1). The individuality of this geographical space is underlined by some aspects: flow orientation from west to east; the foehn process frequency determines the decrease of nebulosity and rainfalls values and the slight increase of thermic values in contrast with locations situated at similar altitudes from the western slopes of Apuseni Mountains; the high humanisation level.

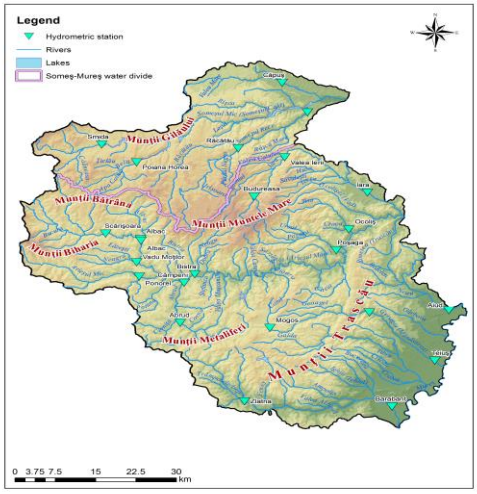

Figure 1. Main relief units

Depending on the altitude there were individualized two distinct geographic areas: the higher mountains and the lower depression (1, 2)

A sketch on identifying runoff regimes types for the rivers from Romania was published in the Physical Geography manual developed by Mihailescu (1936), but a systematic analysis was performed until 1957 by Lazarescu & Panait I. (3), and also in 1972 and 1980 by Ujvari (1972, 1980).

2. DATABASE AND METHODS

For this study there were taken into account three periods: a longer one (1950 - 2009) and two shorter ones (1950-1967 and 1970-2009). The last one allowed the processing of data from 24 representitive hydrometric stations. After analysing the percentage values of seasonal flow from the three periods, it can be observed that winter flow percentage values from were high in the period 1950 – 2009, and the autumn flow values were smaller than those from the other periods (Fig. 2). The spring flow percentage values from the three periods were very close one to the other in the Arieşul Mare and Iara basins, and higher for the Răcătău

and Ampoi rivers basins; those from 1950-2009 slightly reduced than those from the oher two periods (Fig. 2).

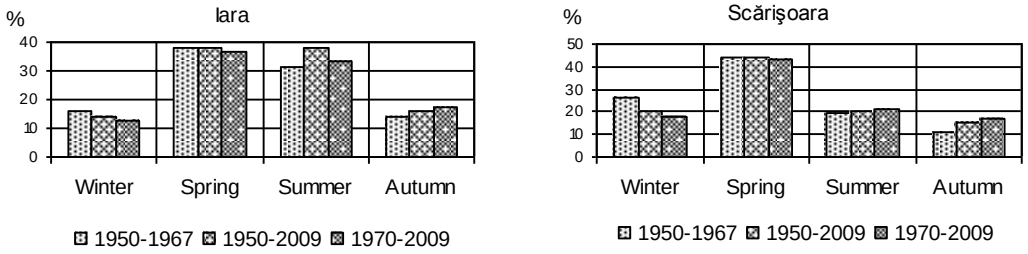

Figure 2. Seasonal flow percentage values from the three periods

In characterizing the main parameters (duration, frequency, variability, averages, seasonal, monthly and extreme values) we applied statistical methods which allowed the identification of the central tendency parameters, also the variability and the form of the data series. The relationships between the specified parameters were evidenced using correlation matrices.

3. RESULTS AND DISCUSSION

The interpretation of the results after the statistical processing of data allowed detecting characteristics on the distribution of river flow during the year

3.1. Seasonal flow regime

The seasonal flow regime in our region depends very much on the climatical conditions, and local differentiations are determined by other physical – geographical factors (4).

3.1.1. The space – time variation of seasonal flow

In winter time (XII - II) the flow repartition over the land depends very much on the thermic regime. The air's negative values keep the snow layer, determines river freezing and draws out a large amount of water from the water circuit. But also the western and south-western influences that bring intercalations of periods with positive temperatures and liquid precipitations on the western slopes of the Apuseni Mountains have a smaller influence on this part. The land differences of seasonal flow values are determined by basin's altitude and by their exposure to western and south-western air masses advection. This is why the smallest percentage values of winter flow (10 – 15% from the annual average volume) appear on the rivers from the Muntele Mare Massive. The high average altitudes of the basins from this area (between 1100 and 1359 m) determines a high frequency of negative temperatures, this way decreasing the possibilities of river supplies from snow melting.

Intermediate winter flow values between 16 – 20% from the annual average volume appear on the rivers Căpuş, Arieşul Mare (with the exception of Neagra Brook) and Aiud. Higher winter flow percentage values are determined by the low basin altitudes of Aiud and Căpuş rivers, and also by the rich underground supplies of the rivers from Arieşul Mare basin.

High winter flow percentage values (20 - 25% from the annual average volume) appear on Abrud River and on the rivers from the lower south - eastern mountainous sector that has a favourable exposure to eastern air masses advection (Geoagiu and Ampoi rivers).

After analysing multiannual winter flow it can be observed that the highest flow values appeared in different winters: 1995/1996 for rivers with high altitude springs (over 1600 m) from Bihor Mountain (Beliş and Someşul Cald rivers) and Muntele Mare Massive (Someşul Rece, Iara and Valea Mare rivers); 1978/1979 on Arieşul Mare, Arieşul Mic, Abrud, Geoagiu and Căpuş rivers; 1981/1982 on Ocoliş, Poşaga and Ampoi rivers. These winters presented climatic conditions favouring river rainfall supplying and successive snow layer melting. Similar situations appeared in the winter of 1969/1970 on Aiud River basin and on the intermediate and lower sectors of Iara River. On most rivers the lowest flow values appeared on the winter of 1983/1984, determined by a persistent anticyclone regime with few precipitations and low temperatures, determining a big part of the river water to be stored up in a liquid phase. Similar situations appeared in the winters of 1992/1993 on the rivers Ampoi, Aiud, Geoagiu, Ocoliş, Poşaga, Beliş and upper

Someşul Cald, 2000/2001 on Ocoliş and Poşaga Rivers, respectively 1986/1987 on Beliş and Someşul Cald rivers (Fig. 3).

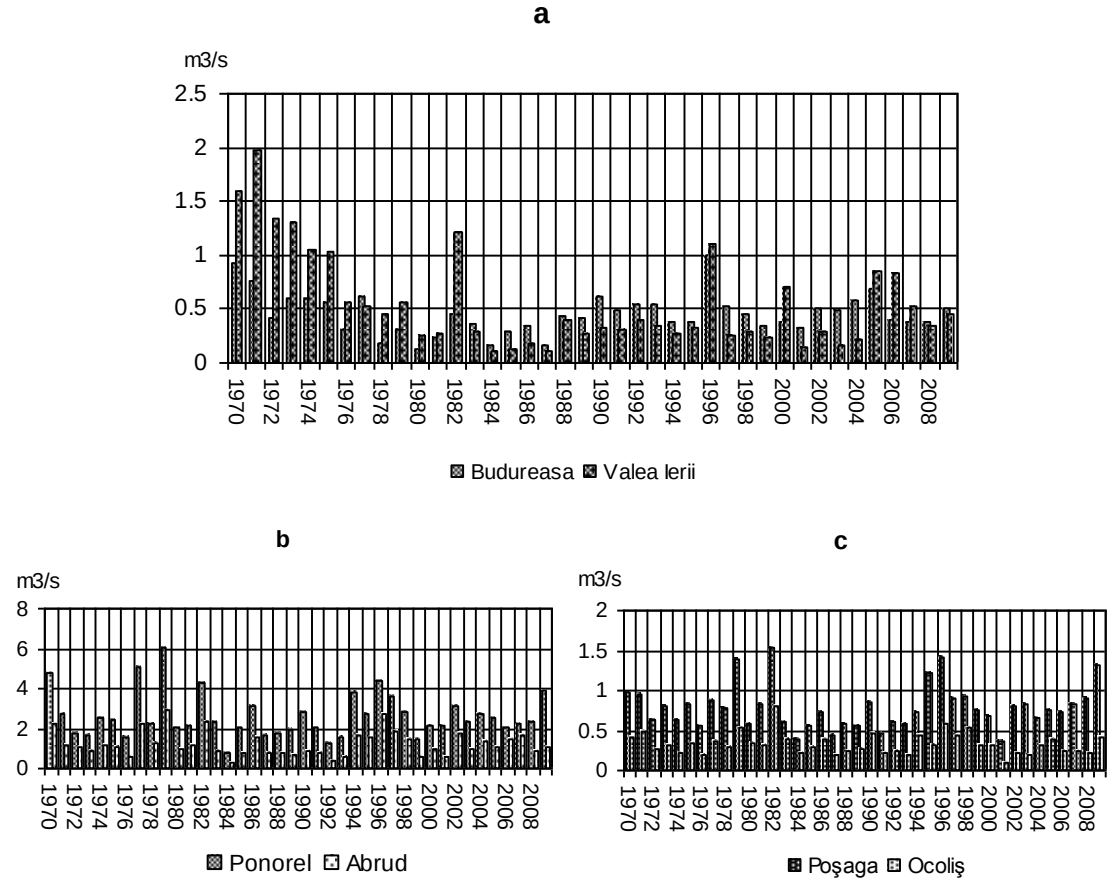

Figure 2. Multiannual variation of winter flow at hydrometric stations from the rivers Iara (a), Arieşul Mic and Abrud (b), Poşaga and Ocoliş (c).

Spring (III - V) represents the highest flow season determined by snow melting, by high rainfalls quantities and low values of evapotranspiration and infiltration into a saturated or partially frozen soil. The average flow volume in this season is high, representing between 38,4 % (Aiud River at Aiud) and 45.4 % (Someşul Cald River at Smida and Neagra River at Vadul Moţilor) from the annual average volume.

Higher spring flow percentage values appear on the rivers from upper Arieş River basin (43- 45 %) and from Metaliferi and Trascău mountains (42-43 %). The gradations are determined by the differences in altitude and drainage basins' exposure from the two study regions. The lowest percentage values (34,8 % and 40 %) appear on the rivers from Muntele Mare Massive, affected by katabatik circulation effect, and on the Aiud River. The highest spring flow appeared on most rivers in 1970, 2005 and 2006 (Table 1). In these years the high water volumes were determined by intense snow melting long time and high intensity frontal rainfalls; 80 – 85% of this volume was drawn off due to high soil humidity. The lowest spring flow values appeared in different years: 1973 in upper Arieş River basin, 1992 on Bistra and Poşaga rivers etc. (Table 1) or in two consecutive years (2002 and 2003 on Abrud and Ocoliş rivers).

In summer (VI - VIII) rainfalls quantities decrease, air temperature increases and the vegetal blanket grows, determining a strong flow decrease. The flow values in this season vary between 15,7 % (Vadu Moţilor) and 34,2 % (Iara River at Valea Ierii). The lowest summer flow values (between 15 and 20 % from the annual average volume) appear on Arieşul Mic basin. Values like 21% to 15 % for the summer flow appear on the rivers from Arieş basin before Câmpeni, and on those from the south-eastern part of the Apuseni Mountains. The highest summer flow values (31% -35 %), very similar to those in springtime, appear on the rivers from the eastern and northern part of the Muntele Mare Massive.

The highest summer flow values were registered in different years: 1974 and 2006 on the rivers from upper Arieş River basin, 1975 on the rivers from region's south-eastern part, and 2005 on the rivers from

Muntele Mare Massive (Table 1). The lowest summer flow values were registered in 2000 and 1993 the rivers from upper Arieş River basin, 2000 on Abrud River, 1992, 1993 and 1994 on some tributaries of Arieş River.

In autumn (IX - XI) the evaporation decreases and the underground supplies are drained out and not renewed. This is why at the beginning of this season appears the low waters period, and at the end of this season floods generated by persistent rainfalls. Autumn has the lowest contribution to the annual average volume (11,2 % - Ampoi River at Zlatna and 19.1 % - Iara River at Valea Ierii). The autumn percentage flow values vary between: 11 and 15 % in the basins of Răcătău River and of the rivers from Metaliferi Mountains; 15,1 and 17 % on upper Someşul Mic (Beliş, Someşul Cald) and Arieş rivers basins (excepting Scărişoara); 17,1-19 % on the rivers from Muntele Mare Massive. On most rivers, the highest autumn flow values were registered in 1972, and the smallest in 1983 and 2000 .

3.1.2. Seasonal flow repartition types

These types were determined by seasons' succession according to their decreasing contribution to annual flow values. An exception is the spring that has the highest values on all rivers from our study region. It has determined that the predominant type is S.W.A. for the rivers in upper Someşul Mic River basin and those from Muntele Mare Massive. *S.W.A. type* is specific for the rivers Arieşul Mare and Arieşul Mic rivers basin and for those in Gilăului Mountains (Căpuş River) and Metaliferi Mountains (Geoagiu and Aiud rivers), draining the surfaces with altitudes of 600 and 1000 m with and with favourable exposure to western air advection. A different type (W.S.A.) can be found on Neagra River (Vadul Moţilor), Abrud River (Câmpeni) and Geoagiu River (Mogoş), with higher seasonal flow in springtime, followed by winter, and with the lowest in autumn. Some rivers present a metamorphosis of the seasonal regime type. So, the upper Abrud River basin belongs to the S.W.A. type, and the lower basin (at Câmpeni) to the W.S.A. type. The Ampoi River at Zlatna belongs to W.S.A. type, and at Bărăbanţ to S.W.A. type. Similar situations appear on Geoagiu River. This phenomenon can be explained by the tributaries' different flow regime that has a strong influence on the main collector's flow regime.

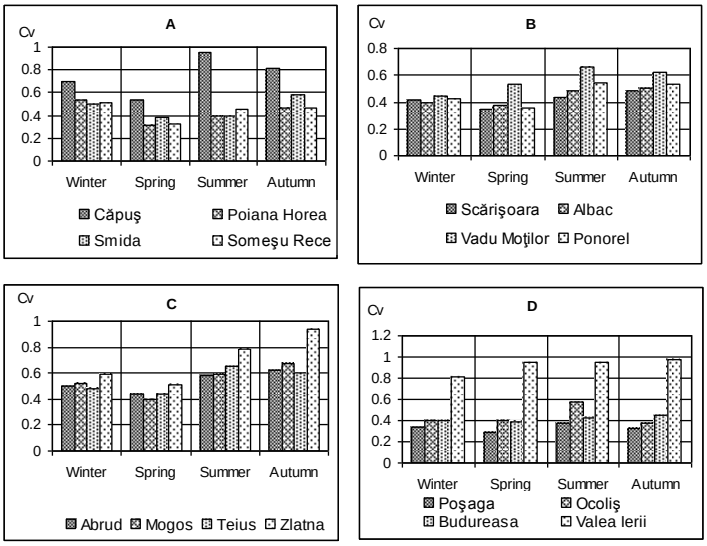

Figure 4. Seasonal variation coefficients values at the hydrometric station from the basins of Someşul Mic River (A) and upper Arieş River (B) – Metaliferi Mts. (C) and Muntele Mare Massiv (D).

3.1.3. Seasonal flow trend and oscillation

Time flow variation was highlighted using variation coefficients. The smaller values of this coefficient in spring and winter reflect a more uniform flow distribution. But in summer and autumn, when the variation coefficients have the biggest values, the land differences are more pronounced. This way the contrasts appear between the western, southern and eastern rivers of Muntele Mare Massive (Valea Mare, Ocoliş, Poşaga and Iara rivers) and those from the upper Arieş River basin (Arieşul Mare and Arieşul Mic rivers). An intermediate situation appears on the rivers from Metaliferi and Trascău mountains (Fig.4).

The seasonal flow evolution trend for the years 1970 – 2009 presents a great land diversity, being determined by natural (especially climatic) and anthropic factors. In winter time most rivers present a stationary flow trend. A slight increasing winter trend was registered on Someşul Cald and Albac rivers, and a more increased trend on Ampoi River at Zlatna. A slight decreasing trend appeared on Arieşul Mic and Abrud rivers and a more acute trend on Iara River at Valea Ierii (Table 1).

Table 1. Seasonal flow's linear trends

Brook	Hydrometric 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
Ocolis	Ocolis	Su	St	St	Su
Posaga	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 Manastirii	St	St	Su	St
Geoagiu	Teius	St	St	Su	St
Aiud	Aiud	St	St	Cu	St
Ampoi	Zlatna	Ca	Ca	St	Cu
Ampoi	Bărăbanţ	St	Ca	St	Su

In springtime, the flow had a stationary trend on the rivers Căpuş, Beliş, Arieşul Mic, Albac, Ocoliş and on the middle and lower Geoagiu River. Slight spring increases were observed on Someşul Cald, Abrud, Valea Mare and Poşaga rivers, and more pronounced on the middle and lower Ampoi River. The deacreasing spring trend was observed on Someşul Rece River and on the upper Iara River (at Valea Ierii). In summer time, the flow evolution trend presented on most rivers a slight or pronounced decreasing trend (Someşul Rece and Arieşul Mic rivers, and the upper courses of Geoagiu and Iara rivers). In autumn time, the flow had a stationary trend on the rivers Căpuş, Beliş, Albac, Abrud, Poşaga, and on the upper Iara River basin, and on the middle and upper Ampoi River basin. It can be observed a strong autumn flow increase on Someşul Cald River and a strong decrease on Iara River at Valea Ierii (Table 2).

3. 2.Monthly flow regime

After analysing the monthly average flow from all over the year, it can be observed that the land differences are determined especially by climatic factor. So, the early snow melting from the mountainous areas of Metaliferi and Trascău mountains, with lower altitudes, determines a maximum flow in March (Fig.4). But the rivers from Bihor Mountains, with high altitudes, present a maximum in April (Fig 4). The rivers from Muntele Mare Massive, with drainage basin altitudes over 1100 m, have the highest monthly average flow in May (fig. 5).

The months with the lowest average flow values are August for the rivers on upper Arieş basin and September for Abrud River. The rivers from Muntele Mare basin present their minimum in winter time, in January on Bistra and Ocoliş rivers, and in February in the upper and middle Iara basin.

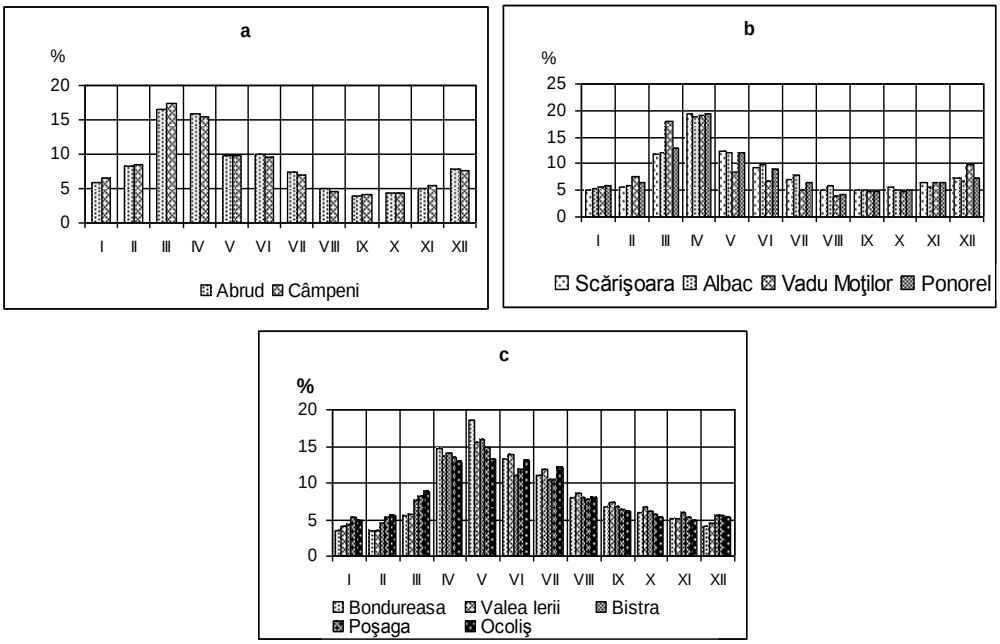

Figure 5. Monthly average flow variation through the year at the hydrometric stations from the drainage basins of the rivers Abrud (a) - Muntele Mare Massive (b) and upper Arieş (c)

The appearance frequency of the highest and lowest average flow months underlines the land contrasts determined by relief's altitude and drainage basins' position, reflected in the climatic conditions (Fig. 6).

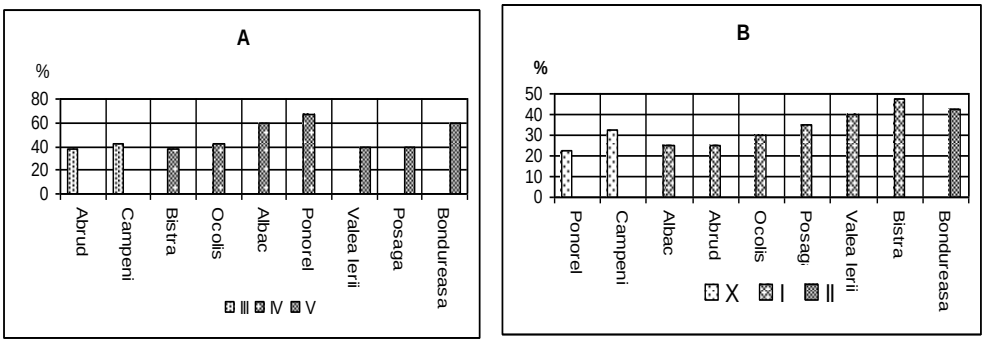

Figure 6. Frequency (%) of months with the high (A) and low (B) runoff (1970-2009)

The land differences are underlined also by the analysis monthly average flow repartition. So, in January, the complete solid form precipitations and the bad weather conditions for snow melting determine low flow values that represent between 3,5 % (Bondureasa) and 6,4 % (Câmpeni River at Abrud) from the annual average volume. Strong contrasts appear between the river on the northern and the southern slopes of Muntele Mare Massive.

In February it can be observed an increase of the drained water volume, especially on the rivers from Arieşul Mic basin (1-1,5 %) and from the Metaliferi and Trascău mountains (2-2,5 %).

In March, April and May appear the highest flow values. The March average flow on the rivers from Abrud basin has values between 16,6 and 17,5 % from the annual volume. The rivers from the upper Arieş basin have values of 18,3 and 19,4 % from the annual volume in April. In May, the values from the rivers on Muntele Mare Massive vary between 13,3 -15,4 % from the annual volume.

The summer and early autumn months present a strong decrease of rainfalls quantities, underground supplies depletion and high evapotranspiration values determined by decreasing river flow values. This decrease becomes more accentuated in August and September due to the lowest monthly flow values, between 3,9 % and 4,9 % from the annual volume.

From November it can be felt a slight flow increase due to the intensification of autumn rainfalls. This month contributes with 5,0 % - 6,5 % from the annual average flow. This rainfall increase determines an increase of monthly flow in December; after that comes a period of flow decrease, in January and February, when the high altitude drainage basins – over 1000 m present the lowest monthly flow values, due to negative temperatures and water freezing. On the rivers from Muntele Mare Massive, the lowest flow values appear in January (Bistra and Ocoliş) and February (upper and middle Iara River basin).

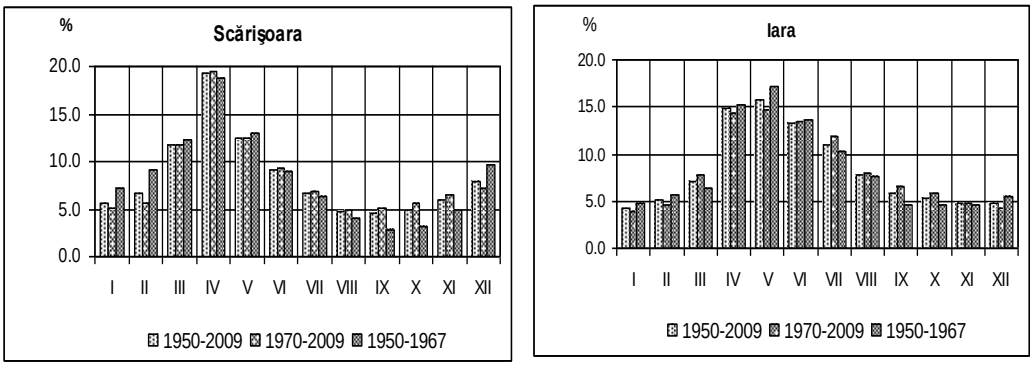

Figure 7. Monthly flow percentage values from the three time periods.

After analyzing monthly percentage flow participation into the annual average volume in the study periods, it can be observed that the monthly average flow regime didn't change very much over the years, with only slight differences in the upper Arieş basin in August – October for the period 1950-1967, with values decrease in contrast with the other two periods (fig.7). In exchange, the percentage values from winter and spring are higher than the others.

The monthly average flow variation description was made using monthly coefficients. The coefficients minimum values appear in May, and the maximum values in winter: December on Abrud River and February on upper Arieş basin, revealing the climatic instability of the last decades. Some high values for the variation coefficients appear on most rivers also in autumn (Table 2).

Table 2. Monthly variation coefficients values (1970 – 2009)

Statia hidrom.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Poiana Horea	0.62	0.83	0.59	0.43	0.43	0.48	0.53	0.49	0.61	0.58	0.57	0.68
Capus	0.91	0.87	0.71	0.69	0.82	1.16	1.22	1.18	1.15	1.02	0.84	0.80
Racatau	0.78	0.94	0.66	0.77	0.66	0.81	0.90	0.75	0.85	0.87	0.76	0.83
Somesu R	0.53	0.49	0.45	0.42	0.51	0.53	0.64	0.47	0.61	0.62	0.49	0.79
Smida	0.57	0.89	0.73	0.48	0.49	0.49	0.50	0.55	0.76	0.74	0.68	0.70
Scărişoara	0.51	0.74	0.55	0.51	0.44	0.55	0.55	0.58	0.69	0.65	0.58	0.61
Albac	0.52	0.71	0.57	0.54	0.45	0.62	0.61	0.57	0.65	0.66	0.62	0.60
Albac	0.52	0.68	0.52	0.54	0.41	0.51	0.48	0.51	0.5	0.52	0.55	0.60
Vadu Moţilor	0.55	0.69	0.66	0.64	0.65	0.75	0.95	0.76	0.93	0.81	0.61	0.73
Ponorel	0.57	0.71	0.59	0.49	0.47	0.68	0.71	0.61	0.81	0.7	0.72	0.59
Abrud	0.70	0.72	0.65	0.53	0.60	0.71	0.80	0.69	0.80	0.81	0.71	0.81
Câmpeni	0.69	0.71	0.64	0.54	0.61	0.74	0.85	0.68	1.04	0.79	0.72	0.73
Bistra	0.52	0.34	0.46	0.44	0.39	0.41	0.43	0.39	0.51	0.40	0.40	0.58
Poşaga	0.55	0.33	0.38	0.41	0.35	0.48	0.51	0.37	0.43	0.36	0.37	0.45
Ocoliş	0.56	0.36	0.54	0.54	0.45	0.59	0.94	0.53	0.53	0.44	0.38	0.61
Bondureasa	0.51	0.45	0.55	0.54	0.43	0.57	0.53	0.44	0.51	0.56	0.53	0.48
Valea Ierii	0.97	0.91	0.89	1.14	0.95	1.06	1.04	0.86	0.92	1.28	0.91	0.88
Iara	0.88	0.93	0.94	1.04	1.00	1.17	1.19	0.90	0.82	1.05	0.78	0.74
Mogos	0.76	0.79	0.58	0.52	0.61	0.82	0.88	0.67	1.07	0.98	0.73	0.83
Valea Manastirii	0.73	0.68	0.56	0.51	0.52	0.72	0.94	0.76	0.91	0.91	0.66	0.70
Teius	0.67	0.63	0.59	0.53	0.56	0.78	1.00	0.73	0.93	0.99	0.69	0.70

Aiud	0.77	0.95	0.87	0.81	0.71	1.00	1.51	1.19	0.84	0.96	0.78	0.87
Zlatna	0.80	0.74	0.70	0.57	0.59	0.87	0.96	1.07	1.22	0.94	0.95	0.83
Barabant	0.66	0.62	0.69	0.52	0.55	0.68	1.85	0.75	0.88	0.93	0.95	0.73

CONCLUSIONS

The study region represents an area of high genetic flow factors diversity. This is why the monthly and seasonal flow regime particularities have a very different space distribution, this way marking off areas with specific characteristics due to natural and anthropical factors. These factors, together with the flow regime particularities, allowed the identification of areas of different flow regimes. These areas are represented by the basins of Arieşul Mare, Arieşul Mic and Abrud. Strong contrasts appear between the drainage basins of the rivers of the southern and northern slopes of Muntele Mare Massive, respectively those from the western and eastern slopes. In the middle and lower Iara basin can be felt some anthropical influences determined by the upper basin catchments.

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