Water resources and wetlands, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

PARTICULARITIES OF SEASONAL AND MONTHLY FLOWING REGIME ON THE SMALL RIVERS OF MARAMUREŞ MOUNTAINS

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Abstract

This region lays over the western part of Maramureşului and Bucovinei Carpathians, known also as the Northern Group of the Oriental Carpathians, with climatic and morphologic particularities that strongly reflect itself into the flowing regime of small rivers. To work out this study there have been elaborated and interpreted data from 16 representative hydrometric stations from the region in study, monitoring the water flow from hydrographic basins with small surfaces, which reflect more closely the local particularities of the river water regime from the surface in study. There have been taken into account the period 1968-20005, which allowed valorizing data came from the hydrometric stations. It's been observed that the rhythmical structure of the water regime reflects the local features of supply sources, relief's geological, morphological and morphometrical conditions. Most of the hydrometric stations present a decreasing or stationary flow trend in all seasons. Seasonal flow frequency shows a strong differentiation between poor and rich flow periods, the same thing that happens for the floods analyze. Variation coefficients group themselves after seasons. Also, the monthly flow characteristics group themselves, especially after variation coefficients.

Keywords: Maramureş Carpathians, flow regime, season, month, variation, trend

1. INTRODUCTION

The region in study lies over the western part of the Maramureş and Bucovina Carpathians. It includes the biggest part of Maramureş Mountains, especially the vast Maramureş Depression, bordered in east by the Maramureş Mountains, in south by the Rodna Mountains, in west by the volcanic Oaş-Gutâi-Ţibleş Mountains. From the south depression corridor there have been taken into account only the Bârgău Mountains, at the border with the Călimani Mountains. Through their geographical position, morphostructural and biopedoclimatic complexity, this unit distinguishes itself through all the other units. The relief diversity overlaps the geological structure. This way, the Neogen eruptive range has absolute heights between 800-1800 m, that rise from north to south. Its favorable exposion to moist air masses advection from west induces a pronounced humidity, that appears especially in landscape features and in rivers water regime, with strong contrasts between the west flank exposed to rainfalls, and the east one, placed in "rain shadow". Excepting Rodna and Bârgău Mountains, all peaks maintain a north-west to south-east orientation. The development of strong water network emphasizes relief fragmentation. The presence of big mountain depressions and gulfs, river corridors and low passes reduce the massiveness of these mountains and induce a remarkable diversity to climatic and also water elements. Thereby, the annual rainfall quantities vary between 1200-1400 mm on the western flanks, and under 1000 mm on the eastern ones, decreasing less than 900 mm in corridors (Romanescu & Romanescu, 2008). The water network gathered by Tisa River in north, Someşul Mare, Someş and Tur rivers in south and west follows the depressions and corridors, with longitudinal sectors when follow the peaks direction, showing an accentuated alignment (Vişeu and Iza Rivers), and cross-cut sectors when crossing the peaks (Salva and Bistriţa Rivers). There appears a high concentration of water network in areas with local subsidence, having a convergent characteristic. There has been used in this study data that come from 16 hydrometric stations from our region (Table 1). They monitor the water flow from basins with areas of less than 100 km^2. There has been taken into account the period 1968-2005, which allowed the use of these data.

Table 1. Multiannual average flow data (1968-2005)

River	Hydrometric station	F (Km^2)	H_{med} (m)	Discharge		Geographic unit
				Q (m^3/s)	q (l/s.km^2)	
Turţ	Gherţa Mare	36.6	315	0.523	14.2	Volcanic mount.
Tur	Negreşti Oaş	38	716	0.891	23.4	Volcanic mount.
Valea Rea	Huta Certeze	61	726	1.782	29.2	Volcanic mount.
Lechincioara	Boineşti	84,6	318	1.009	11.0	Volcanic mount.

Talna	Vama	51	604	1.212	23.8	Volcanic mount.
Tarna	Tarna Mare	26.8	394	0.337	12,6	Volcanic mount.
Vişeu	Poiana Borşa	134	1284	3.924	28.3	Maramureş Mt.
Ţîşla	Baia Borşa	63.4	1307	2.366	37.3	Maramureş Mt.
Ruscova	Luhei	185	1177	6.023	32.6	Maramureş Mt.
Iza	Săcel	68.4	898	1.519	22.2	Volcanic mount.
Boicu	Dragomireşti	91.8	928	2.016	17.1	Volcanic mount.
Botiza	Şieu	97.8	797	1.541	15.7	Volcanic mount.
Cosău	Fereşti	114	744	2.188	19.2	Volcanic mount.
Anieş	Anieş	132	1200	3.317	25.1	Rodna Mt.
Sălăuţa	Romuli	39	939	0.233	6.0	Rodna Mt.
Straja	Mureşenii Bârgâului	71,0	997	1.416	19.9	Bârgău Mt.

2.SEASONAL FLOW REGIME

The seasonal flow variation is determined by the characteristics of the climatic elements and is the main feature of the area river flow. The main feature is represented by the river's dominant flow in spring or winter time (in rare cases), with the smallest percent in autumn time (Table 2).

2.1.Space-time variation of seasonal flow

Table 2 Percentual values of seasonal flow (1968 – 2005)

Hydrometric station	Flow's percentual values			
	Winter	Spring	Sum-mer	Autumn
Gherţa Mare	36.3	34.0	18.4	11.3
Negreşti Oaş	26.5	38.6	17.2	17.6
Huta Certeze	27.0	37.6	17.2	18.2
Boineşti	41.2	32.2	10.5	16.1
Vama	28.7	38.0	17.0	16,3
Tarna Mare	36.3	34.0	18.4	11.3
Poiana Borşa	12.8	38.2	29.3	19.7
Baia Borşa	13.8	39.1	27.4	19.7
Luhei	15.6	41,7	24.3	18.4
Săcel	18.4	37.8	24.3	19.5
Dragomireşti	20.4	40.6	21.6	17.4
Şieu	22.3	40.5	20.1	17.1
Fereşti	21.9	39.1	20.7	18.3
Anieş	16.2	42.1	24.4	17.3
Romuli	16.3	39.7	24.4	19.6
Mureşenii Bârgâului	16.8	43.3	22.5	17.3

Territorial variations of seasonal flow values are determined by the reception basins altitude and by their exposure to moist air masses advection from west.

In *winter* (XII - II), the flow space distribution is influenced especially by the rainfall small quantities (rarely under liquid form) and by the thermal regime. The air's negative temperatures maintain the snow layer, determine river's freeze-up and evacuate big water quantities from the water circuit.

The percent of winter water flow from the annual average flow volume varies according to altitude and basins position in front of the dominant air masses. Thereby, the flow values decrease in winter time from the west part of the volcanic mountains exposed to the advection of warm and moist oceanic air masses, with a high snow layer instability, with a higher frequency of positive temperatures days and with rainfall periods, to the higher eastern and southern sector, from Maramureş and Rodna Mountains, with altitudes that exceed in some places 1800 m.

On the rivers from west Oaş Mountains, with basins low average altitudes (300-400m), the winter flow values exceed those from spring, representing 36-41% from the entire annual volume (Fig. 1). Instead, the stations from Maramureş Mountains (Vişeu, Ţâşla, Ruscova), Rodna Mountains (Anieş, Romuli) and Ţibleş Mountains (Iza) present the lowest winter values, representing between 12.8% (Vişeu at Poiana Borşa) and 18.4% (Iza at Săcel) from the average annual volume (Fig. 1). Average river basins altitudes from above are higher (between 900 and 1300 m), determining a high frequency of negative temperatures, diminishing river supplies from snow melting. Intermediate percentual values of winter flow (between 20-30% from annual volume) are higher (between 26-29%) on Tur and its left tributaries (Rea Valley and upper Talna) and lower (20-22%) on upper Iza basin (Boicu and Botiza Rivers).

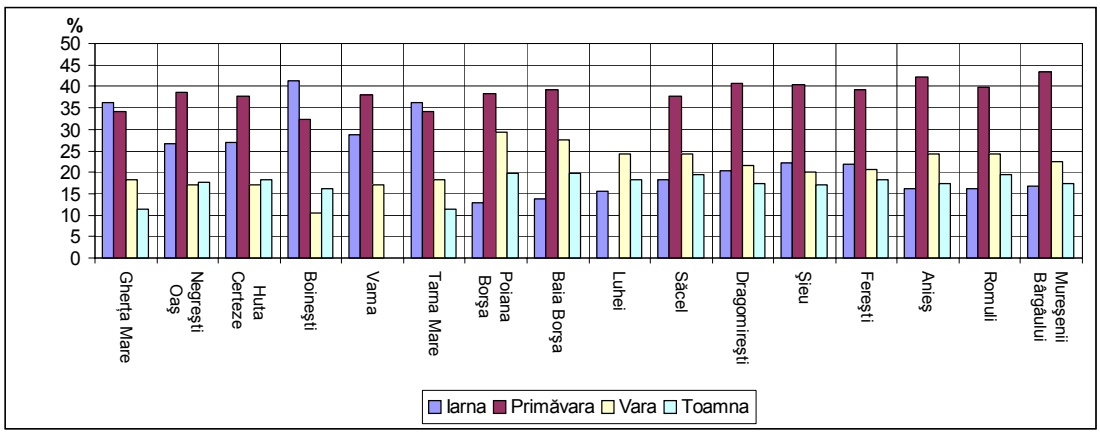


Fig.1. Percentual values of seasonal flow

Tur and Bistriţa Basins rivers had the highest flow values in the winter of 1978/1979, when appeared climatic conditions for rainfalls river supply, and also for successive snow layer melting. Similar conditions appeared in the winters 1995/1996 on Anieş and 2004/2005 on Anieş and Ţâşla (Fig. 2). The lowest values for winter flow appeared in 1983-1984, because of the persistent high pression regime with low rainfalls and low temperatures, determining that most of the water to be laid into solid phase.

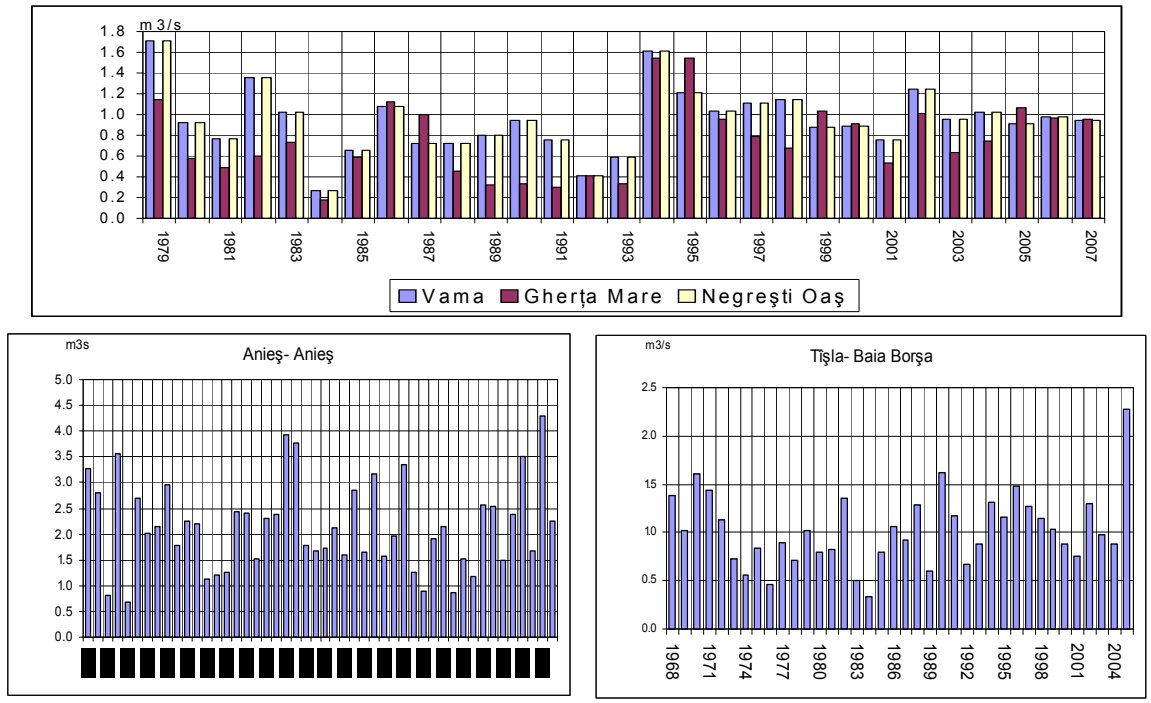


Fig.2. The variation of multiannual winter flow profile on Anieş, Ţîşla ,Tur and Turţ rivers hydrometric stations

Spring (III - V) represents on almost every river the season with the most abundant flow determined by snow melting, high relative rainfalls quantities and low evapotranspiration values. Once the temperatures rise above 0°C, the melting phenomenon begins gradually and in tiers, reflecting it into the springtime high waters. The springtime floods appear according to melting rate, rainfalls length and intensity, determined by snow melting, rainfalls or the overlapping of the two.

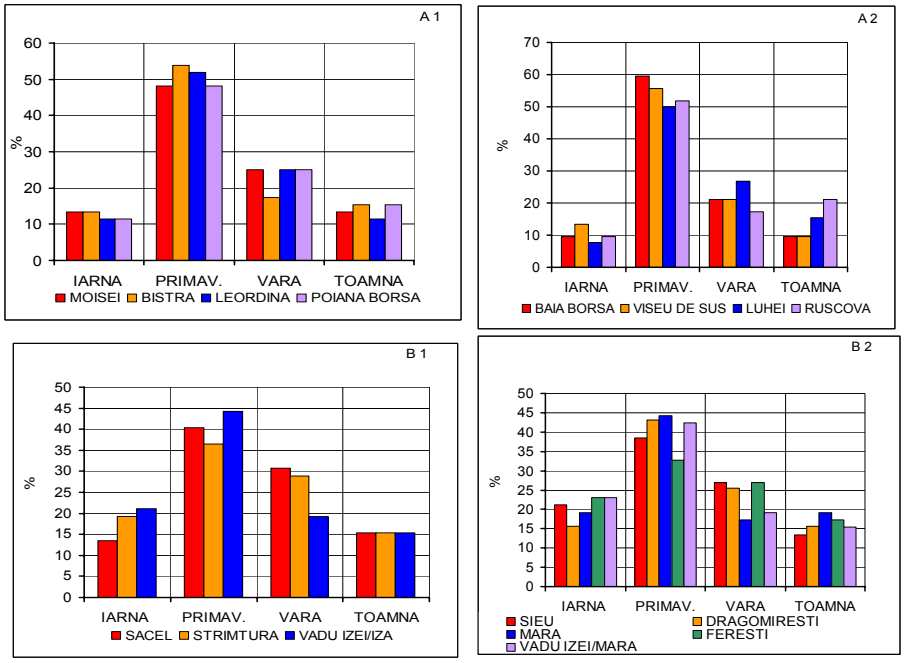


Fig.3. Floods seasonal frequence on rivers from Vişeu (A) and Iza (B) basins (after M.Cocuţ, 2005).

The average flow volume in this season is high, representing 32.2 (Boineşti) – 43.3% (Mureşenii Bârgăului) from the annual average volume. The highest volumes appear on rivers that drain water from Rodna and Bârgău Mountains (39-43%) and from Iza and Vişeu upper basins, and also from Ruscova basin (Table 2); the lowest volume appear on Tur basin (32-38%). The highest spring flow values appeared in different years: 1985 and 2000 on Tur basin (Lechincioara, Tarna and Turţ Rivers, and also on Valea Rea and Tur Rivers). In these years, the frontal rains had long periods and high intensity, enough to generate important flow volumes, 80-85% due to high substratum moisture. Similar situations appeared in 1970 on upper Vişeu and Anieş Rivers, and in 2005 on Ţâşla River. The lowest spring flow values appeared in different years: 1990 on most rivers from Tur basin, 2003 on Ţâşla River and 1972 on Straja and Tarna Rivers. Spring flow features can also be illustrated through floods frequency. The data analyze of Maramureş Depression stations show that spring flow is the most important, with 50-60% on Vişeu basin and 35-45% on Iza River. The other seasons have much lower values. The Vişeu basin presents less than 20% in winter. Similar values appear on the small rivers from Iza basin in winter and autumn (15-20%).

In *summer* time (VI-VIII), the decrease of rainfalls quantities, the increase of air temperature and the growth of vegetal cover intensify the evapotranspiration, fact that highly diminishes the flow values. Low summer waters apparition also diminishes underground supplies. When convective (sometimes frontal) rainfalls appear, also appear summer floods, with very high amplitudes; they generate flash floods such as those from June 1970, June 1974, and July 1980 etc. From the annual average flow, 10.5% (Boineşti) and 29.3% (Poiana Borşa) appear in summer time. On upper Vişeu and Iza basins, on Ruscova River and on the rivers from Bârgău Mountains and from the southern Bârgău Mountains flanks, the summer flow values are greater than those from winter time (20-30%). On Tur Basin Rivers, the summer flow is smaller than that from winter (Table 2). The summer flow values decrease happens in reverse sense from those in winter season. The values decrease to 10.5% at Boineşti (on Lechincioara River) and to 17.2% at Negraşti Oaş (on Tur) and Huta Certeze (on Valea Rea). However, some extreme cases appeared. The highest summer flow appeared in different years: 1980 and 1998 on Tur Basin Rivers, 1974 on Ruscova River and on upper Vişeu basin, 1955, 1974 and 1994 on Anieş, Salva and Straja Rivers. This thing shows the importance of summer convective rainfalls on flow generation. The lowest summer flow values appeared in 2003, 1992 and 2006 on Tur Basin Rivers. In these years there were 20 days with no rain, leading in the depletion of several small basin surface rivers.

In *autumn* (IX-XI), the vaporization decreases and autumn rains appear, and also there are no more underground supplies. As a result, the beginning of this season presents a low waters period. The end of autumn time may bring back some floods.

Autumn has the lowest contribution to annual average volume (11.3-19.7%), although the rainfall quantities are twice than those from winter. Autumn flow distribution presents obvious contrasts, caused by climatic conditions oscillations. The region's southern part presents a higher flow (18-19%) than the northern part (16-18%). Exceptional minimum autumn flow values appear at Gherța Mare and Tarna Mare (11.3%). The highest autumn values appeared at the end of the last century (1980, 1998, 1972 and 1974).

2.2.Seasonal flow oscillation and trend

Flow time variation can be represented by variation coefficients. The analyze of seasonal variation coefficient values shows that most rivers have the highest values in summer time (0.35-1.06%) and the lowest in winter (0.30-0.47%)(Table 3). The lowest spring and winter coefficient values reflect the more uniform flow distribution nature. By contrast, summer and autumn coefficients have the highest values, with more pronounced land differences. Also, the highest contrasts appear on rivers from western volcanic flanks, and from western Rodna and Maramureş flanks. Medium contrasts appear on rivers from eastern Oaş and Ţibleş flanks.

Table 3. Season variation coefficients (C_v)

Hydrometric station	Flowing coefficient values			
	Winter	Spring	Summer	Autumn
Gherţa Mare	0.47	0.45	1.06	0.96
Negreşti Oaş	0.33	0.30	0.74	0.68
Huta Certeze	0.34	0.30	0.61	0.57
Boineşti	0.41	0.39	1.18	0.80
Vama	0.33	0.29	0.74	0.69
Tarna Mare	0.49	0.49	0.84	0.84
Poiana Borşa	0.30	0.25	0.36	0.41
Baia Borşa	0.37	0.29	0.30	0.36
Luhei	0.30	0.31	0.35	0.43
Săcel	0.40	0.35	0.49	0.45
Dragomireşti	0.44	0.31	0.55	0.60
Şieu	0.48	0.35	0.63	0.65
Fereşti	0.41	0.33	0.62	0.54
Anieş	0.40	0.31	0.33	0.44
Romuli	0.48	0.29	0.37	0.43
Mureşenii Bârgâului	0.50	0.29	0.49	0.60

The seasonal flow evolution from 1968-2005 years shows us that most hydrometric stations displayed a decrease/stationary flow trend in all seasons. The same decrease trend appeared also in seasonal rainfalls sums from the same period. The seasonal flow evolution from above showed also that 53% of the winter flow displayed a stationary trend. Winter flow trend displayed a higher growth on Turţ River (Gherţa Mare station) and a slightly growth on upper Vişeu and Iza basin, and Ruscova River.

Table 4. Trends of seasonal variations

River	Hydrometric station	Winter	Spring	Summer	Autumn
Turţ	Gherţa Mare	Ip	I	Ip	Ip
Tur	Negreşti Oaş	St	St	St	St
Valea Rea	Huta Certeze	St	I	I	Is
Lechincioara	Boineşti	I	St	D	I
Talna	Vama	St	I	D	Is
Tarna	Tarna Mare	St	Is	D	St
Vişeu	Poiana Borşa	Is	St	Ds	Is
Ţîşla	Baia Borşa	I	Is	St	St
Ruscova	Luhei	Is	St	Dp	Is
Iza	Săcel	St	St	Dp	Is
Boicu	Dragomireşti	Is	St	Ds	St

Botiza	Şieu	Is	I	Ds	Is
Cosău	Fereşti	Is	Is	St	Is
Anieş	Anieş	St	St	D	Is
Sălăuţa	Romuli	St	St	Ds	I

I - Increase
Is - slow
Ip - pronounced
St - Stationary

D – descrease
Ds - slow
Dp - pronounced

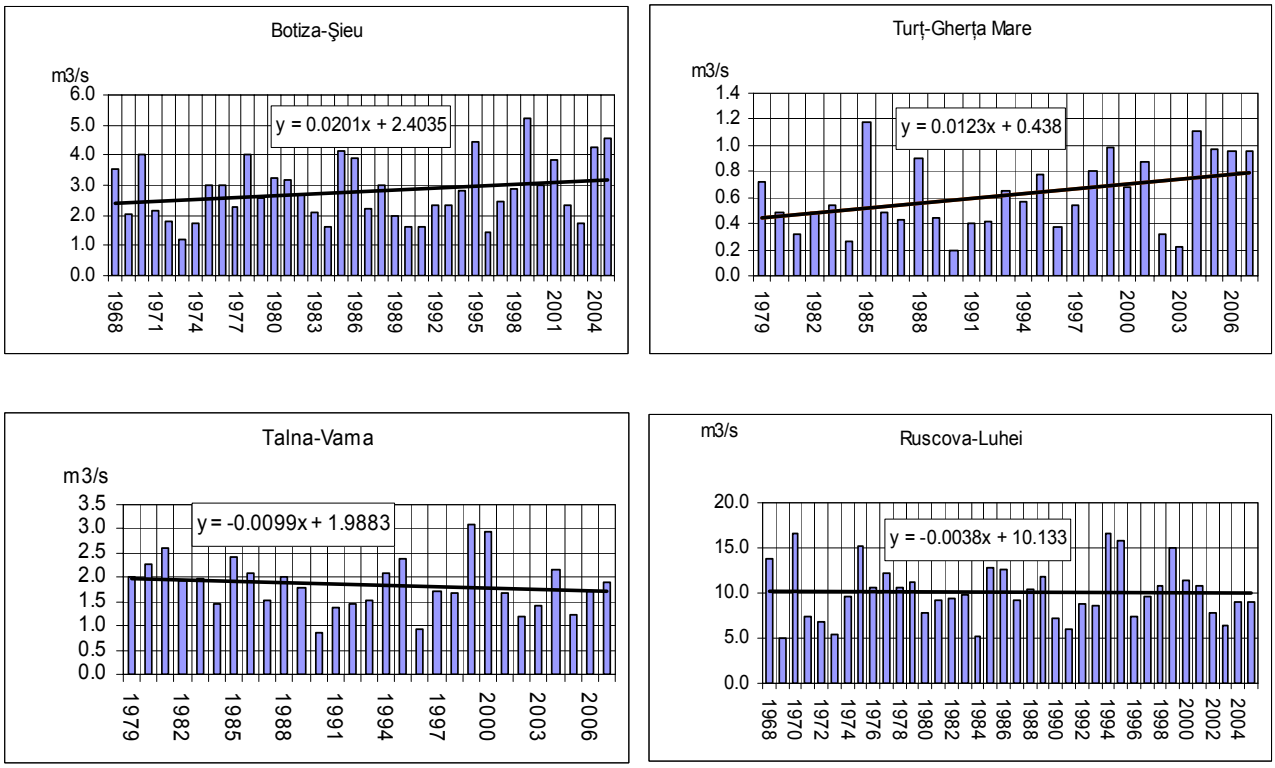


Fig.4. Models for river flow trends

In spring time, most hydrometric stations presented a stationary flow trend. Only a few stations from Tur basin (Gherţa Mare, Huta Certeze, Tarna Mare) and upper Vişeu (Baia Borşa) presented an increasing flow trend, higher on Turţ River (Fig. 4).

3. MONTHLY FLOW REGIME

Monthly average flow analyzes presents important territorial difference determined by climatic factors. Thereby, the western part of the Oaş volcanic Mountains presents a March maximum. On the other hand, rivers with upper basin above 1200 m present a May maximum.

Most hydrometric stations present a maximum in April (Table 5). Appearance frequency of highest average flow months in a year shows also the land differences determined by climatic conditions. The western volcanic mountains rivers exposed to oceanic warm and moist air masses advection present the highest appearance frequency of monthly average flow in March (Fig. 5). But the rivers from upper Maramureş and Rodna basins have the highest appearance frequency in May, and the maximum values grow in a year with the average basins altitudes grow (Fig. 5). Land differences appear also in the average flow repartition analyze of every month. So, the January precipitations have almost exclusively a solid form and there are very small conditions for snow melting, things that determine low flow values – 3.9% (Poiana Borşa) and 12.9% (Boineşti) from annual average volume. In the western part of the area, the monthly average flow values grow from south to north, where the thermal instability is higher than the southern one.

February values present a volume increase with 2-4% to the previous month, especially on volcanic mountains rivers (Table 5).

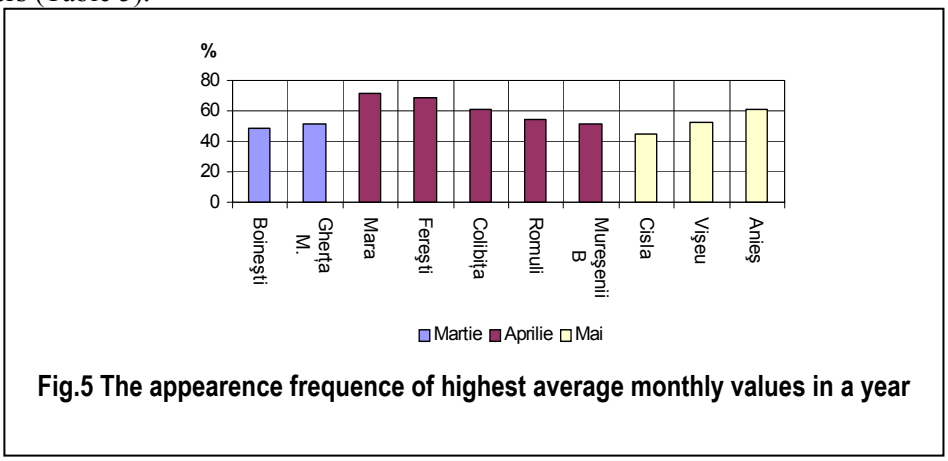


Fig.5 The appearence frequence of highest average monthly values in a year

Table 5. Monthly average flow repartition in a year (% from average flow 1968-2005)

Hydr. station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Gherţa Mare	11.5	13.5	13.7	9.3	6.8	6.61	6.8	3.3	4.5	5.0	7.7	11.3
Negreşti Oaş	7.9	8.1	12.7	14.2	8.8	6.7	6.1	3.1	4.2	4.7	7.3	8.4
Huta Certeze	8.3	9.3	14.1	14.5	8.9	7.4	6.0	3.7	4.6	5.4	8.1	9.5
Boineşti	12.9	15.6	17.2	9.2	5.8	4.4	4.5	1.6	2.8	4.5	8.8	12.7
Vama	8.8	10.5	14.4	14.7	8.8	7.5	6.5	2.9	3.6	4.9	7.8	9.5
Tarna Mare	10.9	14.0	13.1	11.0	9.9	8.4	7.8	2.2	2.3	3.4	5.6	11.4
Poiana Borşa	3.9	3.7	7.1	13.6	17.6	12.7	10.1	6.5	6.5	6.6	6.6	5.2
Baia Borşa	4.3	4.2	7.2	15.3	16.7	10.7	9.7	6.9	7.0	6.0	6.6	5.3
Săcel	5.2	6.0	10.9	15.0	11.9	10.5	8.5	5.3	6.5	6.1	7.0	7.1
Luhei	4.8	4.7	8.7	17.1	16.0	10.0	8.3	5.9	5.8	5.6	7.0	6.0
Dragomireşti	5.6	6.9	13.2	15.8	11.6	9.8	7.6	4.2	4.8	5.7	6.9	7.8
Şieu	6.0	7.7	14.9	16.2	9.5	8.5	7.2	4.4	4.5	5.2	7.4	8.5
Fereşti	6.0	8.0	12.8	16.1	10.2	9.1	6.9	4.7	5.1	5.8	7.4	7.9
Anieş	4.8	5.3	9.0	16.5	16.6	10.4	7.9	6.1	5.1	5.4	7.4	7.9
Romuli	4.9	6.2	10.1	17.7	11.8	9.6	8.6	6.2	6.2	6.4	8.1	7.9
Mureşenii Bârgâului	4.5	5.8	13.9	18.9	10.7	10.1	7.9	4.6	5.3	5.7	7.0	7.1

In March, the rivers from volcanic mountains have the highest annual flow, with 12.7-17.2% from the annual average volume (Fig. 6).

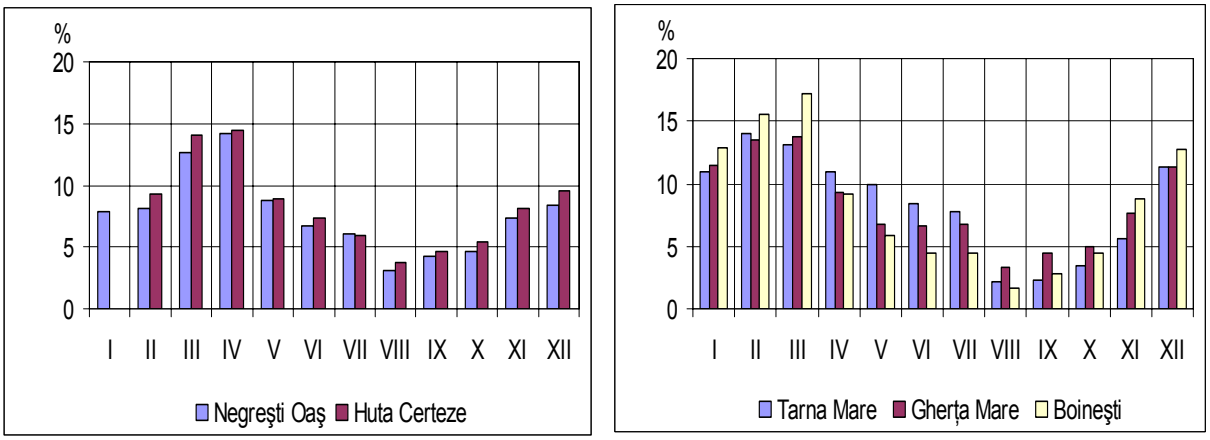
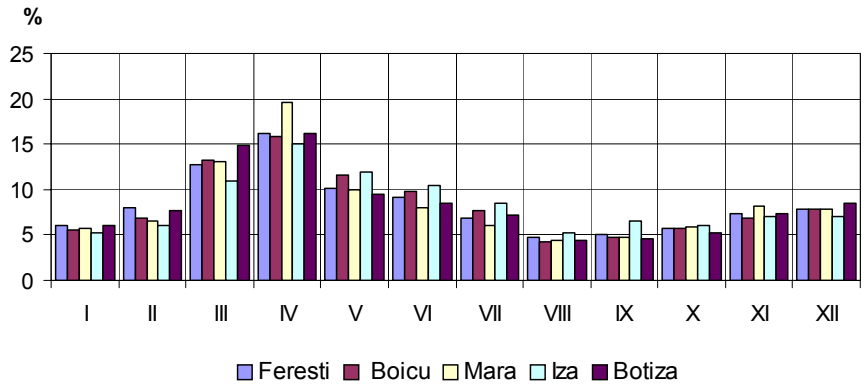


Fig. 6. Monthly average flow variationin a year on western Oaş Mountains rivers.

In April starts a gradual decrease of flow volumes, the strongest in August and September, when appears the lowest monthly average flow – 2.2-8.2% from the annual flow (Fig. 7).



Fig,7. Monthly average flow variationin a year on hydrometric stations from eastern Oaş-Ţibleş Mountains Rivers

The strong decrease of rainfall quantities, the depletion of underground supplies and high evapotranspiration values are the causes for the decrease of river flow values. On Rodna Mountains Rivers, the decrease appears in June, the lowest values appear in September and October (Fig. 8). In November starts a slow flow increase, determined by autumn rainfalls intensification. The average flow of this month represents 5.6-8.8% from the annual average volume. In December appears a strong decrease of flow values from the eastern part of the volcanic mountains. Our monthly average flow variation analyzes used monthly coefficients. On most of the rivers, the lowest coefficients values appear in April, and the maximum ones in summer time and at the beginning of autumn (Table 6). On Anieş, Salva and Straja, the maximum variation coefficients values appear in winter and autumn time. The highest monthly variation coefficients values appear in summer time (Table 5). These months presents frequent droughts and short time rains, with little hydrological effect.

Table 6. Values for monthly variation coefficients – Cv (1968 – 2005)

Hydr. station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Gherţa Mare	0.69	0.67	0.65	0.58	0.90	1.04	1.14	1.47	1.28	1.12	0.88	0.71
Negreşti Oaş	0.46	0.53	0.49	0.44	0.64	0.78	0.98	0.78	0.81	0.92	0.84	0.59
Huta Certeze	0.43	0.55	0.47	0.44	0.45	0.70	0.82	0.62	0.70	0.79	0.64	0.54
Boineşti	0.67	0.61	0.65	0.58	1.12	1.15	1.53	1.58	1.05	1.14	0.82	0.62
Vama	0.49	0.5	0.46	0.45	0.64	0.74	1.03	0.96	1.11	0.92	0.75	0.54
Tarna Mare	0.86	0.58	0.66	0.52	0.96	1.08	1.47	0.65	0.89	1.27	0.99	0.69
Poiana Borşa	0.38	0.39	0.44	0.44	0.25	0.43	0.54	0.38	0.49	0.54	0.59	0.41
Baia Borşa	0.41	0.47	0.46	0.47	0.34	0.39	0.43	0.36	0.49	0.37	0.51	0.49
Săcel	0.55	0.66	0.51	0.44	0.61	0.62	0.66	0.70	0.70	0.62	0.57	0.57
Luhei	0.36	0.36	0.61	0.46	0.39	0.41	0.46	0.34	0.50	0.51	0.66	0.48
Dragomireşti	0.72	0.75	0.56	0.45	0.61	0.72	0.66	0.61	0.90	0.79	0.69	0.62
Şieu	0.64	0.71	0.57	0.48	0.67	0.74	0.84	0.91	0.98	0.88	0.76	0.77
Fereşti	0.65	0.64	0.53	0.46	0.50	0.82	0.75	0.71	0.79	0.72	0.62	0.55
Anieş	0.47	0.57	0.71	0.40	0.38	0.36	0.45	0.44	0.55	0.52	0.74	0.58
Romuli	0.72	0.59	0.60	0.48	0.43	0.52	0.52	0.38	0.56	0.45	0.72	0.69
Mureşenii Bârgâului	0.61	0.81	0.45	0.46	0.54	0.68	0.62	0.56	0.79	0.79	0.77	0.70

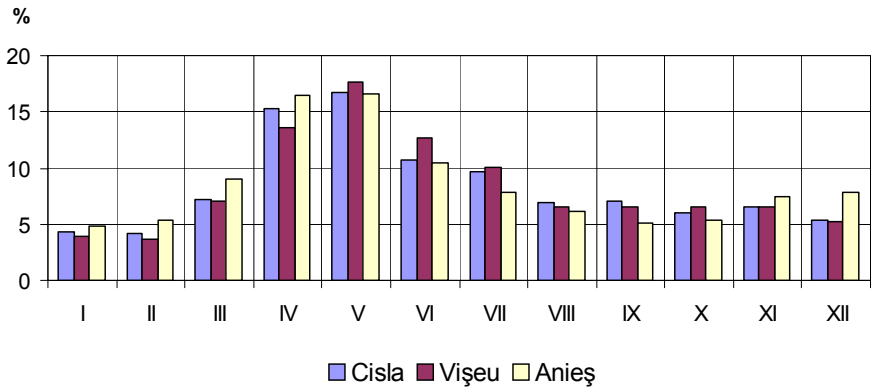


Fig.8. Monthly average flow variationin a year at hydrometric stations from upper river basins Rodna and Maramureş Mountains.

CONCLUSIONS

Maramureş Carpathians represent a region with a very high genetic factors and flow influence diversity. According to this, the laws of seasonal and monthly flow present differences from an area to another. There have delimitated 4 such areas, with flow regime variations. Seasonal variations show characteristics laws, with characteristic space-time variations being one of the most important. They are important in the absolute values analyze, but also in the analyze of the relative ones. Flow's variation oscillation and trend reveal a remarkable order, with dominance of the decreasing trend. We can remark amplitudes in the monthly flow values analyze, differentiated after the basin's geographical position. Here coefficients are grouped only at the minimum values, the maximum ones having a random variation. The Maramureş Mountains diversity manifests itself not only through geological, orographical, climatic and vegetal characteristics, but also through the characteristics of the flow regime, as a consequence of the other factors action and influence.

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