SEASONAL DISCHARGE REGIME OF THE RIVERS IN THE TRANSYLVANIAN SUBCARPATHIANS AND THE ADJACENT MOUNTAINOUS SPACE BETWEEN TÂRNAVA MARE AND NIRAJ

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ABSTRACT.- Seasonal discharge regime of the rivers in the Transylvanian Subcarpathians and the adjacent mountainous space between Târnava Mare and Niraj. *The studied region is situated in the North-East of the Transylvanian Depression and includes two distinct units: the Transylvanian Subcarpathians and the Moldavo-Transylvanian Carpathians, comprised between the valleys of Târnava Mare and Niraj. The study is based upon the processing and interpretation of data coming from 13 hydrometric stations. In order to emphasize the particuliarities of the seasonal discharge regime, we took into account three periods (1950-1967, 1950-2009 and 1970-2009). The characteristics of the geographic coating from the studied area, especially the climatic and geomorphic ones, are clearly reflected in the discharge regime of river waters. Thus, on all rivers, spring discharge is predominant, and winter and autumn are the seasons with the lowest weight of the multiannual average volume. We have underlined the particuliarities of the three subtypes of seasonal regime and we have defined the limits of the corresponding display areas. The variation of the seasonal discharge on a multiannual level was outlined with the help of variation coefficients. Likewise, we also determined the discharge tendencies for the three studied intervals. The analysis carried out has revealed the fact that the rhythmic structure of the hydric system reflects the local characteristics of the supplying sources, of geological, as well as morphological and morphometrical conditions of the relief.*

Keywords: regime, seasonal, monthly, type, subtype, Transylvanian Subcarpathians, Moldavo-Transylvanian Carpathians

1. Introduction

The studied region comprises rather large surfaces from two distinct geographic units: the Transylvanian Subcarpathians and the Moldavo-Transylvanian Subcarpathians (Fig.1). this fact determines a great diversity of geographic conditions with multiple implications on the formation and evolution in time of the water resources of the rivers which drain them. The altitudinal differentiation between the two geographic subunits mentioned determines the orientation of the hydric flow from east to west. At the same time, the litho-structural characteristics of the substrate have led, because of the differences in altitude, to the separation of several sections, with different orientations and flow speeds of the hydric flow.

A draught regarding the identification of the types of hydric regime of rivers in Romania was published in the handbook of Physical Geography elaborated by V. Mihăilescu (1936), but the systemic analysis was carried out in 1957 by Lăzărescu D. and Panait I., and in 1972 and 1980 by I. Ujvari.

2. Database and methods

In order to elaborate the analysis of the seasonal discharge regime, we took into account three periods: a long one (1950-2012) and two shorter ones (1970-2012 and 1992-2012). The latter has allowed for the harnessing of data coming from a number of 13 representative hydrometric stations. From the analysis of data regarding proportional values that seasonal

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discharge has in fulfilling the annual average volume in the three periods, there are no noticeable differences, the calculated values being fairly equal (fig.2). We can mention a few aspects that are specific to the analyzed periods, determined by the climatic changes in the three compared periods. Thus, the instability of winters in the interval 1992-2012 is seen in the fact that the proportional values of winter discharge were somewhat higher than those in the periods 1950-2012 and 1970-2012 (Fig. 2).

For most of the hydrometric stations studied, the proportional values of spring discharge in the three periods studied have remained fairly close. We notice a higher contribution of spring discharge in the period 1950-2012 to the realization of annual average volume.

On the rivers in the Niraj and Târnava Mică basins, the proportional values of summer discharge in the periods 1950-2009 and 1970-2012 are slightly higher than those in the period 1992-2012.

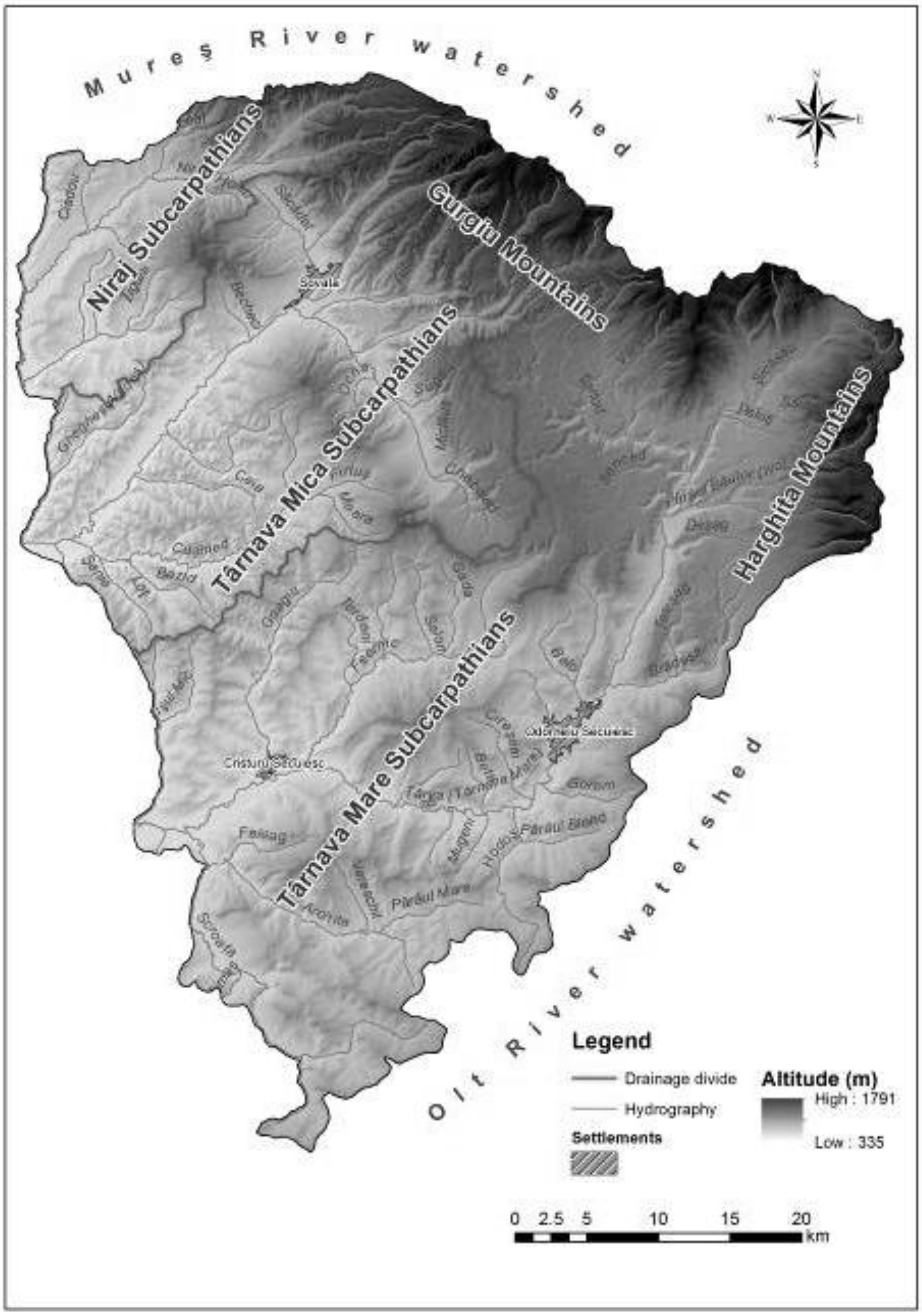

Fig.1. *Map of units of relief*

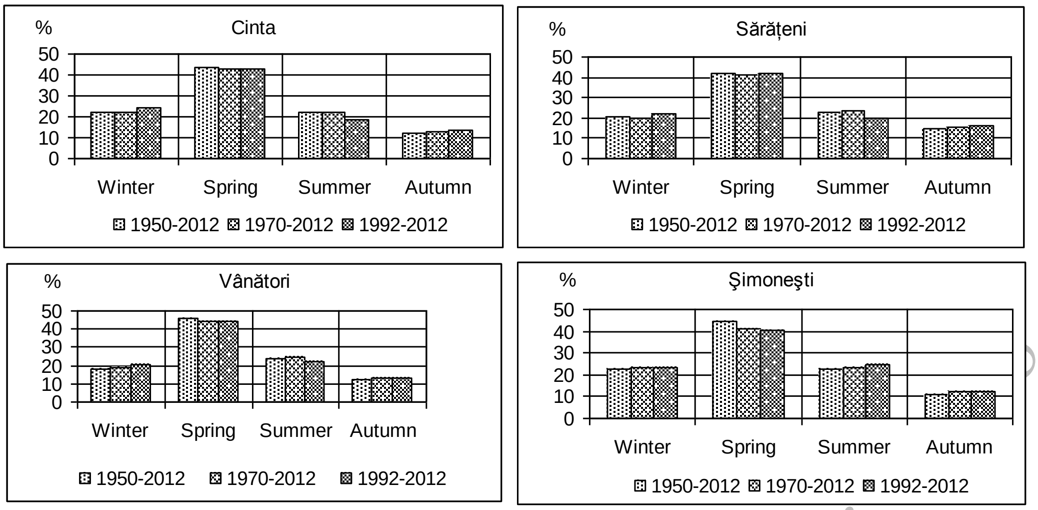

Fig.2. *The proportional values of seasonal discharge in the three studied periods.*

Table 1. *Proportional values of seasonal discharge in the studied periods (1950-2012, 1970-2012 and 1992-2012)*

Hydr. station	WINTER			SPRING			SUMMER			AUTUMN		
	1950 2012	1970 2012	1992 2012	1950 2012	1970 2012	1992 2012	1950 2012	1970 2012	1992 2012	1950 2012	1970 2012	1992 2012
Cinta	22.1	22	24.5	43.4	42.9	43.1	22.4	22.4	18.8	12.1	12.7	13.7
Sovata	20.5	20.9	23.1	39.5	37.6	38.2	24.1	24.5	21.0	15.9	17.0	17.7
Sărățeni	20.6	20	21.9	41.8	41.2	41.7	23.0	23.2	20.2	14.7	15.6	16.1
Crişeni	24.6	25.8	27	43.5	40.8	42.3	20.8	21.1	18.7	11.1	12.3	11.9
Bezid	-	-	21.9	-	-	44.0	-	-	21.6	-	-	12.5
Vărşag	16.0	15.2	17.2	47.4	46.9	45.8	23.1	23.4	21.7	13.5	14.5	15.3
Zetea	-	-	18.6	-	-	43.2	-	-	22.8	-	-	15.4
Odorohei	17.5	17.2	19.3	44.4	43.2	43.3	24.4	24.8	22.5	13.6	14.8	14.9
Vânători	18.4	18.5	20.6	46.1	44.3	44.4	23.6	24.5	22.1	11.9	12.8	12.9
Şicasău	17.5	16.9	18.8	43.5	42.4	40.7	24.5	25.2	23.8	14.4	15.5	16.7
Nicoleşti	22.8	23.2	27.2	45.4	42.0	41.6	22.2	24.1	20.3	9.5	10.7	10.9
Şimoneşti	22.5	23.1	23.2	44.3	41.4	40.2	22.4	23.3	24.4	10.9	12.1	12.2
Saschiz	21.5	21.4	23.1	47.2	44.4	47.1	22.8	24.9	21.8	8.5	9.3	7.9

The proportional values of autumn discharge in the three periods remain close, observing a slight increase of values during 1992-2012, better distinguished on the rivers in the Niraj and Târnava Mică basins.

In characterizing the main parameters (duration, frequency, variability, average, seasonal, monthly and extreme values of data) we applied statistic methods which permitted the identification of the parameters of central tendency, of the variability and shape of series. The relations between the mentioned parameters were emphasized using the correlation matrix.

From the analysis of the three periods we notice the fact that on all rivers spring discharge is dominant, and the least weight within annual average volume is carried by the autumn and winter discharges (table 1)

3. Results and discussions

The interpretation of the results obtained after the statistic processing of the data has allowed for the identification of particuliarities regarding the distribution of river discharge throughout the year.

3.1. Seasonal discharge regime

The distribution of the seasonal discharge of rivers in the studied area is closely dependent on the climatic conditions, and there appear local differentiations, under the influence of the other physico-geographical factors.

3.1.1. Spatio-temporal variation of seasonal discharge

The spatial variation of seasonal discharge is linked to altitude, as a synthetic expression of the vertical zonality of the determinant and conditional factors. The seasonal variation of discharge is determined by the characteristics of the main climatic elements. The dominant feature of rivers in our country, including those in the studied region, lies in the fact that the weight of spring discharge is much higher than that in other seasons (fig.3).

In *winter* (XII-II), the regional distribution of discharge is greatly influenced, not only by the quantity of rainfall (rarely liquid), but also by the thermic regime. The negative temperatures of the air preserve the snow layer, cause rivers to frost and put a large quantity of water out of circulation.

The weight carried by the winter season to the realization of the annual volume of average discharge differs depending on altitude and the position of the mountain sides towards the dominant directions of movement of the air masses. Thus, the highest proportional values of winter discharge (20%-27% of the annual average discharge volume) are recorded on the rivers which drain the Subcarpathian region (Cuşmed, Bezid) and on the rivers with favorable exposure to the advection of air masses from the west (the Niraj and Târnava Mică basins (fig.4). Conversely, on the rivers whose average altitude of the reception basins exceeds 900 m, these values remain between 15% and 20%. The explanation lies in the high frequency of negative temperatures, which diminish the possibilities for rivers to feed with snow melting.

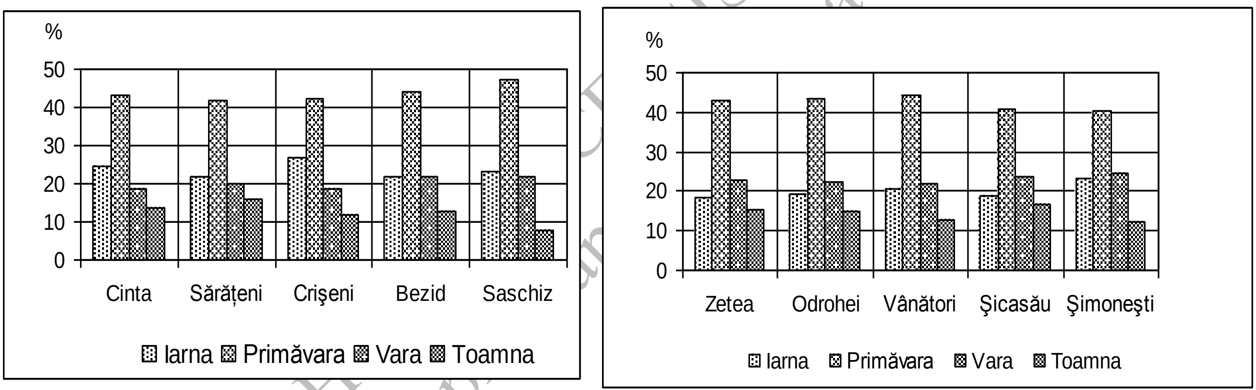

Fig. 3. *The proportional variation of seasonal discharge*

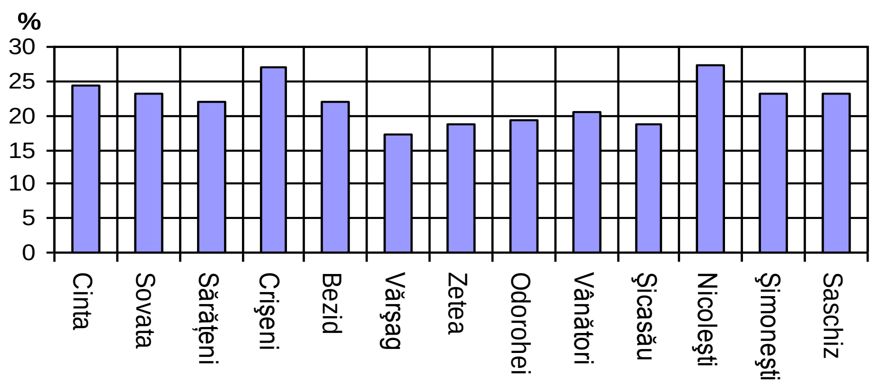

Fig. 4. *The spatial distribution of proportional values of winter discharge*

From the variation of winter discharge on a multiannual level, we notice the fact that the highest values of discharge occurred in different winters: 1978/1979 on Niraj and the rivers in the upper basin of Târnava Mică; 1995/1996 on Târnava Mare and 1981/1982 on some affluents of Târnava Mare (Hodoș, Scroafa) and Târnava Mică (Cușmed), received in the Subcarpathian region. In the afore mentioned winters, there existed climatic conditions which favored the brooks to feed with rainfall, especially from the successive melting of the snow layer. On most rivers, the lowest discharge values occurred in the winters of 1963/1964 and of 1983/1984, characterized by a persistent anticyclonic regime with low rainfall and low temperatures, which made the greatest part of river waters to be stored in solid shape.

The proportional value held by winter discharge of rivers in the Niraj and Târnava Mare basins (21%-25%) exceeds that in the summer.

Spring (III-V) represents the season with the highest discharge, conditioned by the melting of the snow, the relatively high quantities of rainfall and the low values of evapotranspiration and infiltration in the soil which is either super saturated or partly frozen. These conditions are reflected in the discharge by the apparition of high spring waters. Depending on the melting rhythm, the intensity of rainfall that occur during this season, there also appear spring freshets generated by the melting of snow, rainfall or both phenomena overlapped. The regional variations are dictated by the differences in altitude and exposure of the reception basins in the two areas: mountainous and Subcarpathian. During this season, the average volume of discharge is high, representing between 38.2% (Târnava Mică in Sovata) and 47.1% (Scroafa in Saschiz) of the annual average discharge volume (Fig. 5).

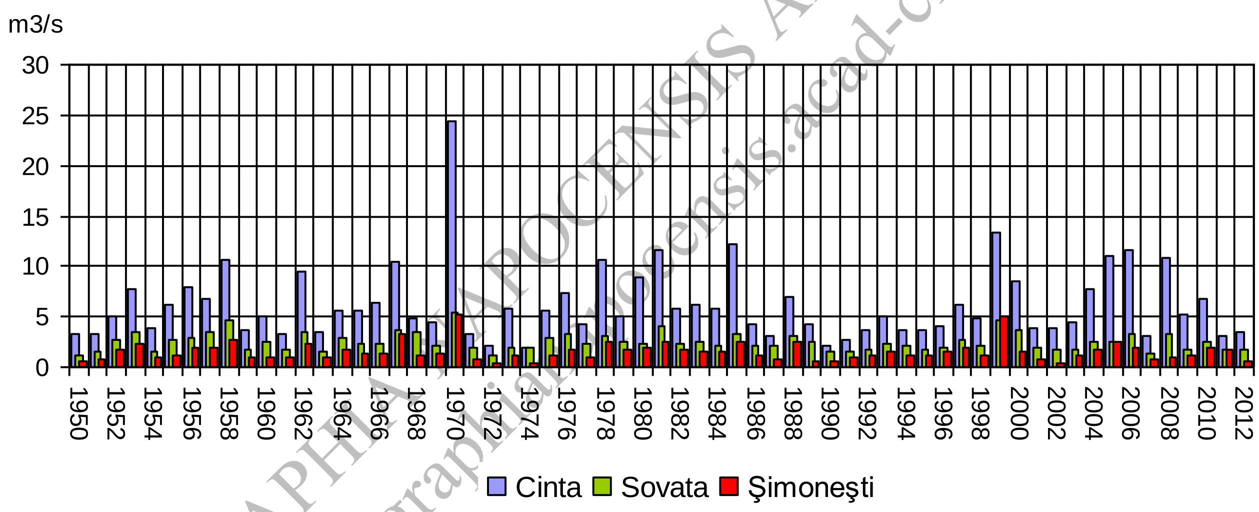

Fig.5. *The chronological variation of spring discharge.*

Higher proportional values of spring discharge are encountered on Niraj, Bezid and the right affluents of Târnava Mare coming from Gurghiu Mountains (43% - 45% of the annual average volume). The lowest proportional values (38% - 41%) are recorded on the upper Târnava Mică and on Șicasău, where the effect of katabatic circulation is felt.

On most rivers, the richest spring discharge occurred in 1970, when the accentuated melting of the snow and long-term frontal rainfall, which were rather high in intensity, generated large volumes of water, which drained in about 80% - 85%, due to the high level of humidity in the substrate.

On most rivers, the lowest values of spring discharge occurred in 1972. Similar situations took place in 1979 on the upper Târnava Mică, in 1974 on Niraj and in 2002 on Feernic (Fig. 5).

In *summer* (VI – VIII) the decrease in the quantity of rainfall, the increase in the temperature of the air and the development of the vegetal carpet lead to the intensification of evapotranspiration, which determines the decrease of the discharge in contrast to the previous season. In addition to this, there is also the decrease in the reserves of subterranean waters. The phenomenon is reflected in the discharge by the apparition of low summer freshets. As a consequence of torrential rainfall, there also appear summer freshets, which can sometimes reach high amplitudes, causing floods. Their frequency is higher in July, but they can also appear in August, as was the case in August 2005 on Feernic. The volume discharged during this season represents between 18.8% (Cita) and 24.4% (Șimonești) of the annual average discharge. The lowest proportional values of summer discharge are recorded in the Niraj and Târnava Mică basins (between 18% and 22% of the annual average volume) and the highest are recorded in the Târnava Mare basin (between 22.1% and 25%).

Compared to the average situation presented, there have been extreme cases. Thus, the highest summer freshets occurred in different years: 1974 on Niraj and on the upper basin of Târnava Mică; 1980 in the Târnava Mare basin and in the upper basin of Târnava Mică; 1998 on Cușmed and Scroafa; 2010 on Feernic and the middle course of Târnava Mare. The lowest values of summer discharge occurred in 1950 in the Niraj and Târnava Mică basin, and in 1952 on the rivers in the Târnava Mare basin. The proportional value of 21%-22% of the annual average discharge specific to the mountainous region exceeds the volume discharged in average during the winter.

In *autumn* (IX – XI), evaporation starts to diminish and the substrate reserves are spent and unrestored. As a consequence, in the beginning of this season there is the period of low waters and towards the end of the season, there can appear freshets generated by possible persistent rainfall. Autumn represents the season with the poorest contribution to the realization of the average annual volume (7.9% Scroafa in Saschiz and 17.7% Târnava Mică in Sovata). The proportional values of autumn discharge remain between: 15% and 18% in the superior basin of Târnava Mică, Șicasău and Hodoșa; 12%-13.5% in the basins of Cușmed, Bezid and Feernic; 13.5% - 15% on Târnava Mare upstream from the Șicasău river mouth. On all rivers, the highest autumn discharge occurred in 1972, and the lowest in different years: 1963 (Cinta, Vărșag, Vânători); 1979 (Sovata) and 1986 (Crișeni).

3.1.2. Types of seasonal distribution of discharge

These were established on the basis of the succession of seasons, in the decreasing order of their contribution to annual discharge, with the exception of spring, which is predominant on all rivers in the studied region.

It has been noticed that V.I.T. type is specific to the rivers in the Târnava Mare basin, with the exception of a few affluents in the Subcarpathian region (Hodoșa and Scroafa).

The V.I.T. type is specific to the rivers in the hydrographic basins of Niraj and Târnava Mică, regions which have a favourable exposure towards the advection of air masses from the west, as well as of some affluents of Târnava Mare originating in the Subcarpathian region (Hodoșa and Scroafa). In the case of this *type,* the highest seasonal discharge, following the spring season, occurs in the summer and the lowest, in autumn (Fig.6).

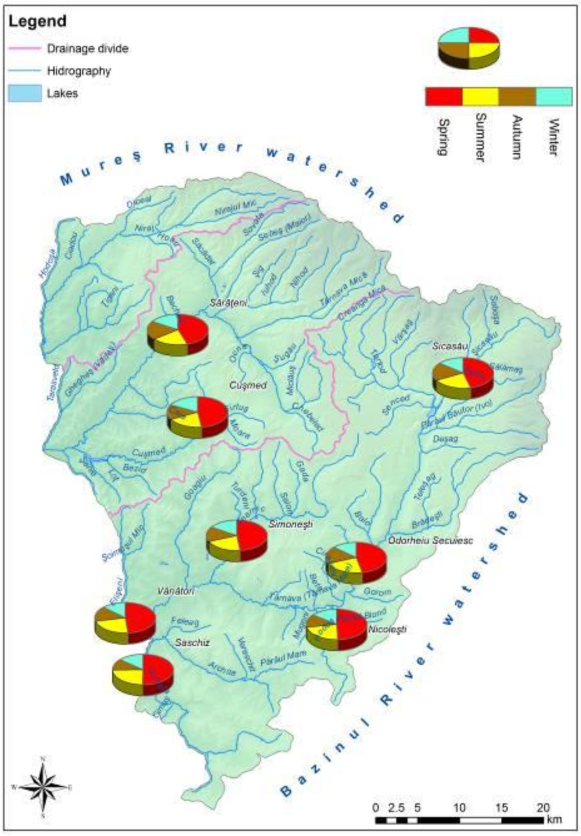

Fig. 6. *Types of seasonal distribution of discharge*

3.1.3. Variation and tendency of seasonal discharge

The discharge variation over time was emphasized by means of variation coefficients. In spring and winter, the lower values of this parameter reflect the more uniform feature of discharge distribution. Conversely, in summer and autumn, when the variation coefficients are at their highest values, regional differences are much more visible. Thus, there appear rather obvious contrasts between the rivers in the Niraj and Târnava Mică basins on the one hand, and those in the Târnava Mare basin, on the other hand (Fig. 7).

The tendency of seasonal discharge evolution in the period 1970 – 2009 exhibits great territorial diversity, being determined by natural factors (especially the climatic ones) and by anthropic ones. In winter, on most rivers, the stationary feature of discharge is emphasized. The slight increase tendency of winter discharge was determined on Târnava Mare at the hydrometric station Odorhei, and was seen as rather high at Vărşag. The slight decrease tendency of discharge was encountered on Hodoşa, Scroafa and Feernic (table 2).

In spring, the stationary feature of discharge was seen on Târnava Mică, in Sovata, and on Târnava Mare at Vârşag, Odorhei and Vânători. On Târnava Mică at Sărăţeni, Feernic and Scroafa, the tendency of spring discharge was that of slow decrease, and on Hodoş and Şicasău that of fast decrease (Fig. 8).

Slight increases of spring discharge were observed on Târnava Mare at Odorhei.

In summer, the tendency of the discharge in the analyzed period, on most rivers, was that of fast or slow decrease (table 2). A slow increase of summer discharge was observed on Feernic, at the hydrometric station Şimoneşti.

In autumn, on most rivers, the tendency of discharge was that of slight decrease, and even fast decrease on the brooks Scroafa and Hodoş (Fig. 9).

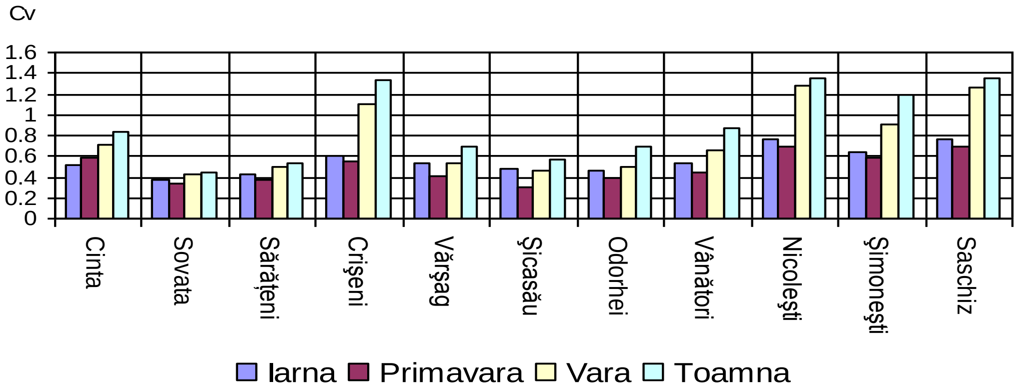

Fig. 7. *The values of seasonal variation coefficients*

Table 2. *Linear tendencies of seasonal discharge.*

Brook	Hydrometric station	Winter	Spring	Summer	Autumn
Niraj	Cinta	St.	Sc.u.	Sc.a.	Sc.u.
Târnava Mică	Sovata	St.	St.	Sc.a.	Sc.u.
Târnava Mică	Sărăţeni	St.	Sc.u.	Sc.a.	Sc.u.
Cuşmed	Crişeni	Cr.u.	Cr.u.	Sc.u.	Sc.u.
Târnava Mare	Vărşag	Cr.a.	St.	Sc.u.	St.
Târnava Mare	Odorohei	Cr.u.	St.	Sc.a.	Sc.u.
Târnava Mare	Vânători	St.	St.	S.a.	Sc.u.
Şicasău	Şicasău	St.	Sc.a.	Sc.u.	Sc.u.
Hodoş	Nicoleşti	Sc.u.	Sc.a.	Sc.a.	Sc.a.
Feernic	Şimoneşti	Sc.u.	Sc.u.	Cr.u.	Sc.u.
Scroafa	Saschiz	Sc.u.	Sc.u.	Sc.a.	Sc.a.

St-stationary, Cr.u.-slight increase, Cr.a.-fast increase,
Sc.u.-slow decrease, Sc.a-fast decrease

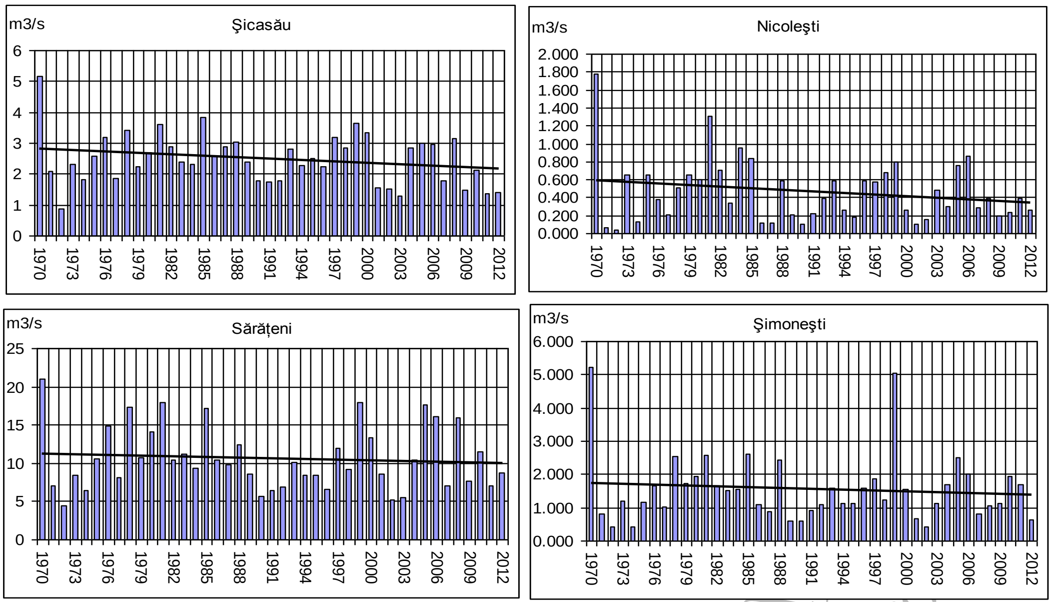

Fig.8. *Tendency of spring discharge (1970-2012)*

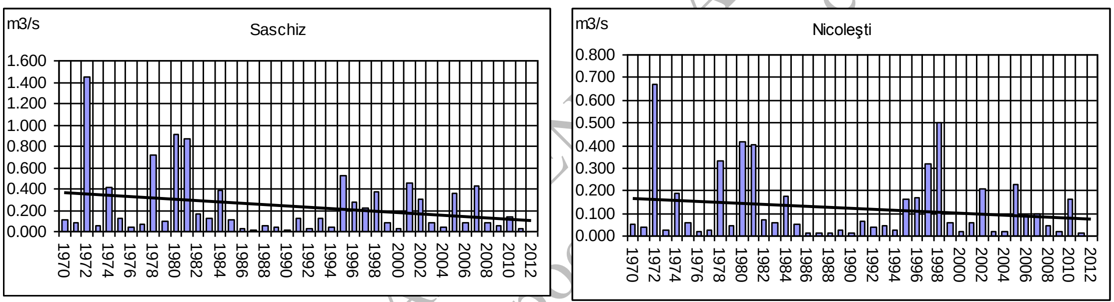

Fig.9 *Tendency of autumn discharge in the period 1970-2012*

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