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VARIATION OF MEAN SEASONAL DISCHARGES IN THE MILETIN RIVER BASIN (MOLDAVIAN PLAIN, ROMANIA)

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Key words: mean seasonal discharge, module coefficient, Hellmann quotient, Pearson coefficient, moving average

Abstract. The hydrographic basin of the Miletin River is situated in the southeast of Europe, in a transitional temperate–continental climate, with considerable variations in the regime of precipitations. The purpose of this study is the spatial and temporal analysis of the mean seasonal discharges, meant to underline the need of implementing regulation projects for the Miletin stream. Furthermore, there are only a few specialized works on this hydrographic basin. The mean seasonal runoff presents significant seasonal and multiannual variations, caused by the high frequency of torrentiality, which characterizes the climate of the Miletin River area. Data from the rainfall stations of Nicolae Balcescu, Chiscareni, and Halceni, as well as from the hydrometric stations of Nicolae Balcescu, Sipote, and Halceni–downstream, respectively, were used. Unlike the stations with a natural runoff regime (Nicolae Balcescu, within the upper basin, Sipote within the middle basin, respectively), for Halceni–downstream (on the lower stream), the artificial runoff underlines a weak correlation with the rainfall regime. The data rows regard periods of 33–59 years, enough to conduct statistical analyses. Data from Halceni–downstream were analyzed, too, though the variables that characterize the hydrologic and rainfall regime within this region concern only 18 years. In the Miletin hydrographic basin, low and high discharge oscillations occur in all the four seasons. This characteristic is very different from those of the great hydrographic arteries that cross the east of Romania: Pruth and Siret.

Introduction

The hydrologic hazard phenomena have multiplied significantly and they have been affecting the local or regional economic activity. This is why scientists should become more interested in elaborating studies to analyze the hydrologic hazard

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phenomena and to determine the natural laws causing them, as well as the necessary measures to fight them. In the territories with few precipitations, seasonal runoff is extremely important for agricultural activities. Depending on the water volume that can be used for farming purposes, one can determine the types of plants to cultivate by the optimal growing period.

The most obvious negative effects become noticeable following floods and droughts. The hydrologic regime of the Miletin River is different from the one of the main collector (Pruth) because its entire hydrographic basin is situated within a single landform (Moldavian Plain), with low altitudes (below 200 m). The hydrologic behaviour is similar to the one of the rivers within the temperate–continental climate with excessive influences specific to the east of Europe. The Miletin hydrographic basin has a vital importance for the local economy because it represents the only economically lucrative exploitable water resource. The lack of financing limits the exploitation of groundwater to private use (only in households).

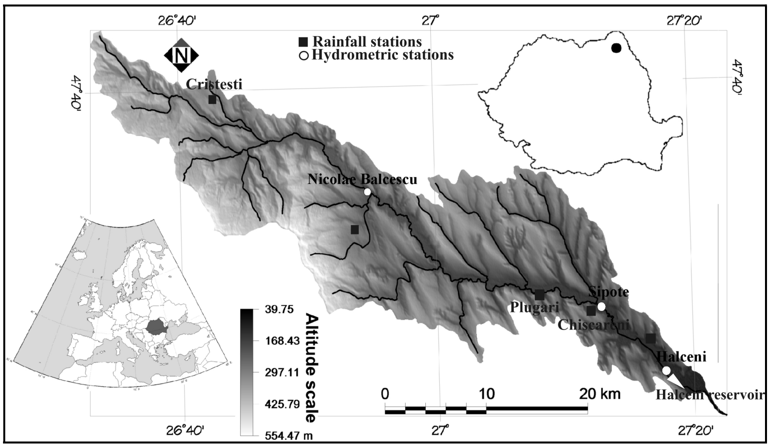

Fig. 1 - Geographic location of the Miletin hydrographic basin and position of hydrometric stations

The mean seasonal streamflows have been thoroughly studied in the national (Calinescu et al., 1997, Pantazica and Schram, 1967, Romanescu, 2009, Romanescu and Nistor, 2011, Romanescu et al., 2011a,b,c, 2012a,b,c) and international literature (Cigizoglu et al., 2005, Dettinger and Diaz, 2000, Machado et al., 2011, McCuen and Beighley, 2003, McKerchar and Pearson, 1994, Parajka et al., 2009, Pilling and Jones, 2002, Silva and Portela, 2012, Villarini et al., 2010, Vinogradov et al., 2010).

This study aims to analyze the seasonal hydrologic hazard phenomena in a region characterized by a rainfall regime with significant monthly and annual oscillations. At the same time, there is an emphasis on the variation in the liquid discharge for the tributaries in the upper basin compared to those in the lower sector.

Regional settings

The Miletin hydrographic basin is situated in the central southeast part of the European continent; it ranges between the parallels of 47º20’25’’ and 47º43’11’’ N. latitude and between the meridians of 26º34’26’’ and 27º21’35’’ E. longitude. The Miletin hydrographic basin is situated in the NE part of Romania and of the Moldavian Plateau. It crosses two geographic subunits: the Suceava Plateau and the Moldavian Plain (Fig. 1). It is an important tributary of Jijia on the right side.

The limit of the hydrographic basin is represented by the watershed that delimits it from the hydrographic basins of the following rivers: Sitna (to the N), Bahlui and Jijioara (to the S), Siret (to the W), and Jijia (to the E). The surface of the Miletin basin (680 km^2, of which 410.24 km^2 on the right side and 269.66 km^2 on the left side) represents 11.72% of the Jijia River basin, 2.45% of the Prut River basin, and only 0.08% of the Danube hydrographic basin.

Materials and methods

For the analysis of mean seasonal runoff, a significant amount of data was used, provided by the Pruth–Barlad Water Basin Administration and by the Moldova Regional Centre of Meteorology, Iasi, under the command of the Romanian National Meteorological Administration. The data were taken from the rainfall stations of Nicolae Balcescu (1962–2008), Chiscareni (1962–1994), and Halceni (1991–2008) and from the hydrometric stations of Nicolae Balcescu (1950–2008), Sipote (1950–2008), and Halceni–downstream (1991–2008). In this sense, the discrete–continuous variables of a maximum 47 terms were processed, some of which long enough to conduct statistical analyses. Data from Halceni–downstream have also been analyzed, though the variables that characterize the rainfall and hydrological regime of this region have an 18-year time limit. The climatic data on temperature were taken from the Meteorological stations in Iasi (in the south of the Moldavian Plain) and Botosani (in the north of the Moldavian Plain), situated about 40 km from the Miletin hydrographic basin.

The entire panel of hydrologic and meteorological data was processed in EXCEL. The processing can be divided into two phases:

-the statistical analysis for which the following parameters were used: arithmetic means, moving averages, frequencies, as well as various calculation formulas to underline the dry and rainy periods according to the Hellmann quotient;

-the elaboration of graphs in EXCEL.

The numerical field model was elaborated using 1:5,000 topographic maps, in the software ESRI ARCWIEW vs. 9. 3. 1. This model helps determining the altimetric levels and the positioning of hydrological and rainfall stations compared to the landform units and subunits. At the same time, there is an emphasis on the slope values, the hill exposure, the longitudinal profile of the stream, etc.

Results and discussions

The seasonal distribution of water volumes carried by a river is determined by the contribution of supplying sources, in their turn significantly influenced by the climatic conditions (McCuen and Beighley, 2003). Though this delimitation is somewhat arbitrary, it does allow a more unitary vision of seasonal hydrologic phenomena.

As for the Miletin basin, the specific of the transitional temperate climate in Eastern Romania gives an irregular aspect to the liquid runoff, marked by important differences in the runoff between seasons (Romanescu et al., 2011a). Following the analysis of runoff variation throughout the year, one can notice important differences of the mean runoff values from one season to another (Table 1, 2; Fig. 2a,b).

Tab. 1 - Seasonal variation of the mean discharges (m^3/s) on the Miletin River for the stations with natural runoff (1950–2008)

Hydrometric station of	**Mean discharges (m^3/s)**				**Mean discharges (%)**				**Annual mean**
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	
Nicolae Balcescu	0.30	0.90	0.49	0.18	16.50	47.94	26.08	9.73	0.47
Sipote	0.91	2.37	1.19	0.54	18.23	47.22	23.72	10.83	1.25

Tab. 2 - Seasonal variation of the mean discharges (m^3/s) on the Miletin River for the Halceni–downstream station (1991–2008)

Hydrometric station	**Mean discharges (m^3/s)**				**Mean discharges (%)**				**Annual mean**
	Winter	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	
Halceni–downstream	0.71	1.63	0.84	1.15	16.52	37.58	19.48	26.42	1.08

During the winter, the NE of the country is dominated by the circulation through a northern component, when cold and dry continental air or cold and wet oceanic air is carried (Pantazica and Schram, 1967, Romanescu et al., 2012a,b). Usually, during this season, the river supply from superficial sources is significantly reduced, as the precipitations (turned into snow) are blocked at the surface. As consequence, within the Miletin basin, the runoff is reduced and the multiannual mean discharge represents almost a fifth of the annual value (Romanescu et al., 2012a).

In the spring, the Miletin River carries – on an average – almost half (44.25%) of the annual runoff. The percentage value of the mean seasonal discharge increases by the altitude (47.22% of the annual runoff at Sipote and 47.94% at Nicolae Balcescu), in rapport with the increase in liquid precipitations and with the higher degree of snow preservation during the winter. On the other hand, at Halceni–downstream, the runoff is more moderate – only 37.58% of the annual value – because of the Halceni dam.

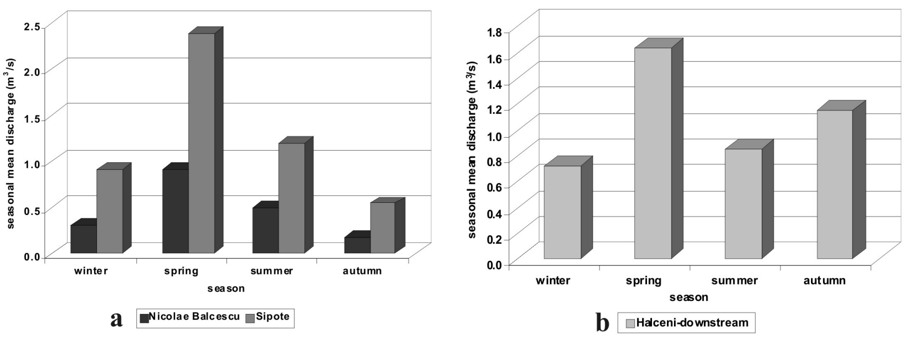

Fig. 2 - a.Seasonal variation of the mean discharges (%) in the hydrographic basin of the Miletin River, for the rainfall stations with natural runoff regime, in the period 1950–2008; b.Seasonal variation of the mean discharges (%) in the hydrographic basin of the Miletin River, for the Halceni–downstream hydrometric station, in the period 1991–2008

In the summer, the water volume carried by Miletin represents 23% of the annual runoff. The values of seasonal runoff, in a natural regime (0.49 m^3/s at Nicolae Balcescu, 1.19 m^3/s at Sipote), clearly underline that the mean seasonal discharge gets very close to the mean annual discharge. During this season, the river gets the supply from precipitations – more intensely in the first part, with maximum rainfall in June. The high temperatures and the rich vegetation determine high potential evapotranspiration (over 110 mm). This way, during a more moderate rainfall, the surface waters are not able to become organized. In this case, surface runoff is ensured mostly by groundwaters. Heavy rains determine an increase in the mean monthly and seasonal runoff, but with relatively low values.

The relatively low amounts of precipitations in the autumn and their intensity raise the water volume carried to almost 16% of the annual runoff. The values increase as the altitude decreases and the surface of the supply basin increases. The mean values of mean discharges are 0.54 m^3/s at Sipote (which represents almost 11% of the annual runoff) and 0.18 m^3/s at Nicolae Balcescu (9.3% of the annual runoff). We find interesting the case of Halceni–downstream where, unlike for the other rainfall stations, a second variation maximum is recorded by 1.15 m^3/s, which represents 26.42% of the annual discharge.

Within the Miletin River basin, there is a seasonal distribution of discharges, specific to the small rivers within a transitional temperate–continental climate. The richest runoff occurs during the spring, because snow melts down and the amount of precipitations increases. The discharge values start dropping until the first half of autumn. In winter, due to brief warm-up periods that interrupt the continuity of the snow layer, there is an increase in the liquid runoff.

The presentation of the multiannual variation of seasonal discharges focuses on the analysis of the module coefficient (K) in order to centre the variables on the same value (the central value of the module coefficient, K=1). The module coefficient (K) is a common index used in the analysis of mean discharge variations. This index expresses the oscillation of the mean annual discharge (Q_{an}) compared to the module discharge (Q_0) and it is calculated as the rapport between the two types of discharges. According to this rapport, when the values of the coefficient are above 1, the runoff is high; if the value drops below 1, the runoff is low; if it is 0, there is no more water in the river.

In the winter, the mean discharge has reduced values. The groundwater supply is more modest, while atmospheric precipitations are blocked as snow or ice on the entire surface of the hydrographic basin. The winter with the most significant runoff was the one of 1998–1999, with 1.52 m^3/s at Nicolae Balcescu and 5.25 m^3/s at Sipote. In Iasi, the mean temperatures in the months of January and February of 1999 presented important positive deviations from the multiannual mean (a +2.4˚C deviation in January and a +2.2˚C deviation in February), which determined warm periods, with positive temperatures. This led to a meltdown of the snow layer in February. The effect of these phenomena was, among others, a rich supply of the Miletin River. At Halceni–downstream, a rich runoff (3.577 m^3/s) was recorded in the period December 1996–February 1997.

The winter of 1953–1954 was the frostiest of the twentieth century. There was a continuous snow layer in the period December 1953–February 1954. This phenomenon represents the main cause for the drop in the runoff values down to 0.004 m^3/s at Nicolae Balcescu and 0.010 m^3/s at Sipote. The lowest mean multiannual discharge for the Halceni–downstream hydrometric station was recorded in 2004 (0.038 m^3/s) (Table 3).

The multiannual variation of module coefficients underlines a period of twenty years (1950–1969) when the runoff was weak in the winter. From 1970 to 1982 (13 years), the mean discharges grew significantly. The lowest period of mean winter runoff was recorded between the years 1983 and 1996 (14 years). From 1997 to 2003, the values of runoff module coefficients recorded significantly high means. After 2003, there has been an obvious decreasing trend of these values. There was a clear alternation of the periods with rich runoff and of those with low runoff within the Miletin basin in the period 1950–2008 (Fig. 3a).

Tab. 3 - Values of maximum and minimum mean seasonal discharges (m^3/s) at the rainfall stations of the Miletin River basin (1950–2008)

Station	**Mean discharge (m^3/s)**	**Winter**	**Spring**	**Summer**	**Autumn**
Nicolae Balcescu	Maximum	1.52	3.46	2.20	1.07
	Minimum	0.004	0.039	0.02	0.00
	Amplitude	1.51	3.42	2.19	1.07
Sipote	Maximum	5.25	8.46	6.19	2.88
	Minimum	0.010	0.13	0.02	0.01
	Amplitude	5.24	8.32	6.16	2.86
Halceni–downstream	Maximum	3.57	4.99	2.05	4.42

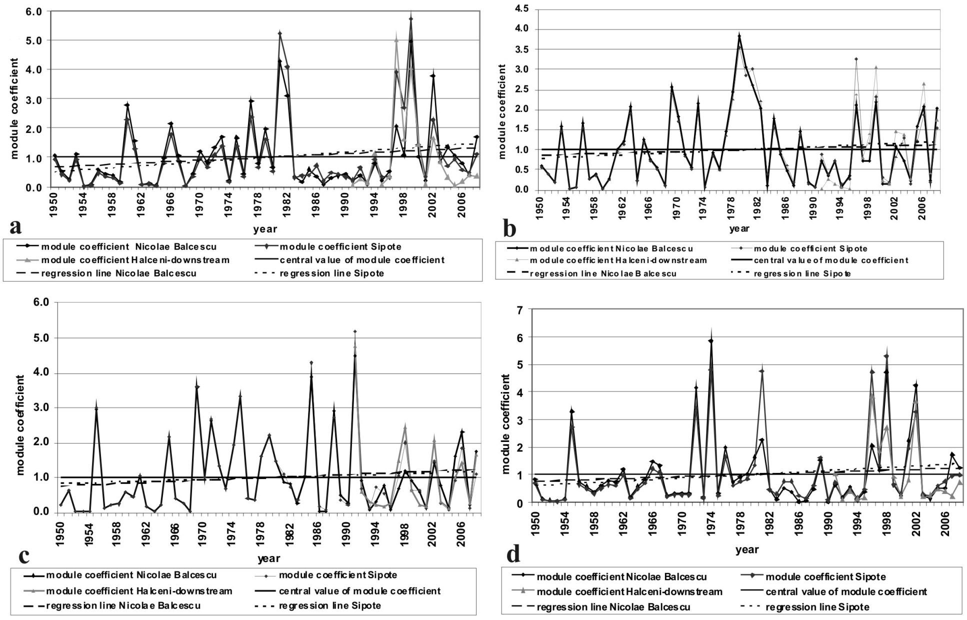

Fig. 3 - Multiannual variation of module coefficients, during the winter (a), spring (b), summer (c) and autumn (d), in the Miletin River basin (1950–2008)

The discharge alternations are generated by both the air temperatures during the winter, and the oscillations of the droughty periods and of those with heavy precipitations. In the period 1961–1969, the mean of winter temperatures was below -1.7^0 C. The particularly cold winters in the NE of Romania determined the solid storage of precipitations. The Miletin River had a low runoff because of the weak supply. The mean winter temperature in the periods 1970–1982 and 1997–2003 exceeded the multiannual mean corresponding to the interval 1961–2008, both in Iasi and in Botosani. These – slightly warmer – winters determined the meltdown of the snow layer in the periods with positive temperatures, thus supplying the streams (which led to richer discharges). Another interval with warm winters was 1983–1996. In this period, the mean discharges on the Miletin River recorded important negative deviations because of the poor rain supply. At Nicolae Balcescu, out of the 42 winter months characteristic to the years 1983–1996, over 60% were extremely dry, very dry, and dry months. In the middle basin, at Chiscareni, 67% of the winter months corresponding to the interval 1983–1994 had qualifiers such as extremely dry, very dry, dry, and little dry (according to the Hellmann quotient). Important positive deviations of the air temperature occurred in the winters of 2004–2008, both in Iasi and in Botosani. The values of the deviations from the multiannual discharge mean were actually low because of a weak supply. During these years, 60% of the 15 winter months were extremely dry, very dry, dry, or little dry (Tables 4, 5, 6).

Tab. 4 - Winter means of the air temperatures and of module coefficients in the upper basin of the Miletin River (1961–2008)

Periods	Mean temperature in Botosani (^{0}C)	Mean multiannual temperature in Botosani(^{0}C)	Deviation	The module coefficient at Nicolae Balcescu	Central value of the module coefficient	Deviation
1961–1969	-3.0		Negative	0.72		Negative
1970–1982	-1.6		Positive	1.6		Positive
1983–1996	-1.4	-1.7	Positive	0.35	1	Negative
1997–2003	-1.3		Positive	1.99		Positive
2004–2008	-0.6		Positive	1.06		Positive

Tab. 5 - Winter means of the air temperatures and of the liquid discharges in the middle basin of the Miletin River (1961–2008)

Periods	Mean temperature in Iasi (^{0}C)	Mean multiannual temperature in Iasi (^{0}C)	Deviation	The module coefficient at Sipote	Central value of the module coefficient	Deviation
1961–1969	-3.3		Negative	0.59		Negative
1970–1982	-1.6	-1.7	Positive	1.6	1	Positive
1983–1996	-1.2		Positive	0.41		Negative
1997–2003	-1.6		Positive	2.5		Positive

2004–2008	-0.8		Positive	0.8		Negative

Tab. 6 - Rainfall qualifiers, according to the Hellmann quotient, at the rainfall stations of Nicolae Balcescu and Chiscareni, in the winter months (1961–2008)

The rainfall stations of	Assessed period	EDM	VDM	DM	MDM	NM	MRM	RM	VRM	ERM
Nicolae Balcescu	1983–1996	15	7	4	2	5	1	2	2	3
	2004–2008	5	3	0	1	1	0	1	1	3
Chiscareni	1983–1994	11	9	3	1	1	3	2	4	3

EDM-extremely dry months; VDM-very dry months; DM-dry months; MDM-moderately dry months; NM-normal months; MRM-moderately rainy months; RM-rainy months; VRM-very rainy months; ERM-extremely rainy months.

At Halceni–downstream, the groups of years that presented low values of the module coefficients during the winter were characterized by means of the air temperatures below the multiannual mean. In the period 1997–2002, the winters were warmer, with several melting down periods, which determined the meltdown of the snow layer and a richer runoff (Table 7).

Tab. 7 - Winter means of the air temperatures and of the liquid discharges in the lower basin of the Miletin River (1991–2008)

Periods	Mean temperature in Iasi (^{0}C)	Mean multiannual temperature in Iasi (^{0}C)	Deviation	The module coefficient la Halceni–downstream	Central value of the module coefficient	Deviation
1991–1996	-1.3		Negative	0.3		Negative
1997–2002	-0.6	-1.1	Positive	2.3	1	Positive
2003–2008	-1.4		Negative	0.4		Negative

In the spring, the runoff values at the three rainfall stations are significantly higher: they oscillate from 3.46 m^3/s to 0.03 m^3/s at Nicolae Balcescu. The highest variation amplitude was recorded at Sipote, the values oscillating between 8.46 m^3/s and 0.13 m^3/s (Table 3).

At Halceni–downstream, a maximum discharge of 4.99 m^3/s in 1999 and a minimum discharge of 0.04 m^3/s in 1994 were recorded. In the periods 1950–1976, 1983–1995, and 2000–2004, respectively, the springs with very low runoff predominated. The periods with rich discharges, recorded at Nicolae Balcescu, Sipote, and Halceni–downstream, are significantly shorter: 1977–1982, 1996–1999, and 2005–2008 (Fig. 3b).

In the summer, the values of the mean liquid discharge vary from 0.029 m^3/s to 2.206 m^3/s, at Nicolae Balcescu, and from 0.02 m^3/s to 6.19 m^3/s at Sipote. The period 1969–1991 presents values over 1 for the module coefficients. The intervals when low values of module coefficients were recorded comprise a great number of years: 1950–1968, 1992–2008 (Fig. 3c).

The amplest oscillations of the liquid discharges, during the autumn, were recorded at Halceni–downstream, from 0.11 m^3/s in 1992, to 4.42 m^3/s in 1996. At the Nicolae Balcescu station, the runoff varied between 0.001 m^3/s and 1.07 m^3/s, while at Sipote, the recorded discharge values fall into a broader interval, between 0.015 m^3/s (in 1953) and 2.88 m^3/s (in 1998). Between 1950–1971, 1982–1995, and 2003–2008, respectively, the runoff was very low, and in the periods 1972–1980 and 1996–2002, the module coefficients had values over 1 (Fig. 3d).

The alternation of periods with high and low discharges, between 1950 and 2008, for the 3 rainfall stations in the Miletin River basin, overlaps partially during all the four seasons. At the two rainfall stations (Nicolae Balcescu and Sipote) – where there is a natural runoff of the Miletin River – the regression line underlines an increasing trend of the values. Except for the summer, the increase in the mean seasonal runoff in the period 1950–2008 was more accentuated at Sipote than at Nicolae Balcescu. The periods with very low runoff recorded precipitation amounts below the multiannual mean, while the years with a rich seasonal runoff are a consequence of seasonal precipitation amounts higher than the average (Table 8, 9, 10).

Tab. 8 - Means of module coefficients and of the seasonal precipitation amounts, in the spring, the summer, and the autumn, at Nicolae Balcescu (1962–2008)

Season	Periods	K	Central value of K	Deviation	Means of the annual precipitation amounts (mm)	Multiannual means of the annual precipitation amounts (mm)	Deviation
Spring	1962–1976	1	1	0	139.3	139.8	Negative
	1977–1982	2.6		Positive	167.9		Positive
	1983–1995	0.55		Negative	138.2		Negative
	1996–1999	1.4		Positive	146		Positive
	2000–2004	0.5		Negative	77.9		Negative
	2005–2008	1.5		Positive	176		Positive
Summer	1962–1968	0.5	1	Negative	205.2	231	Negative
	1969–1991	1.5		Positive	246		Positive
	1992–2008	0.8		Negative	221.5		Negative
Autumn	1962–1971	0.7	1	Negative	106.9	113.2	Negative
	1972–1981	1.9		Positive	135.8		Positive
	1982–1995	0.4		Negative	89		Negative
	1996–2002	2.2		Positive	152.3		Positive
	2003–2008	0.7		Negative	95.7		Negative

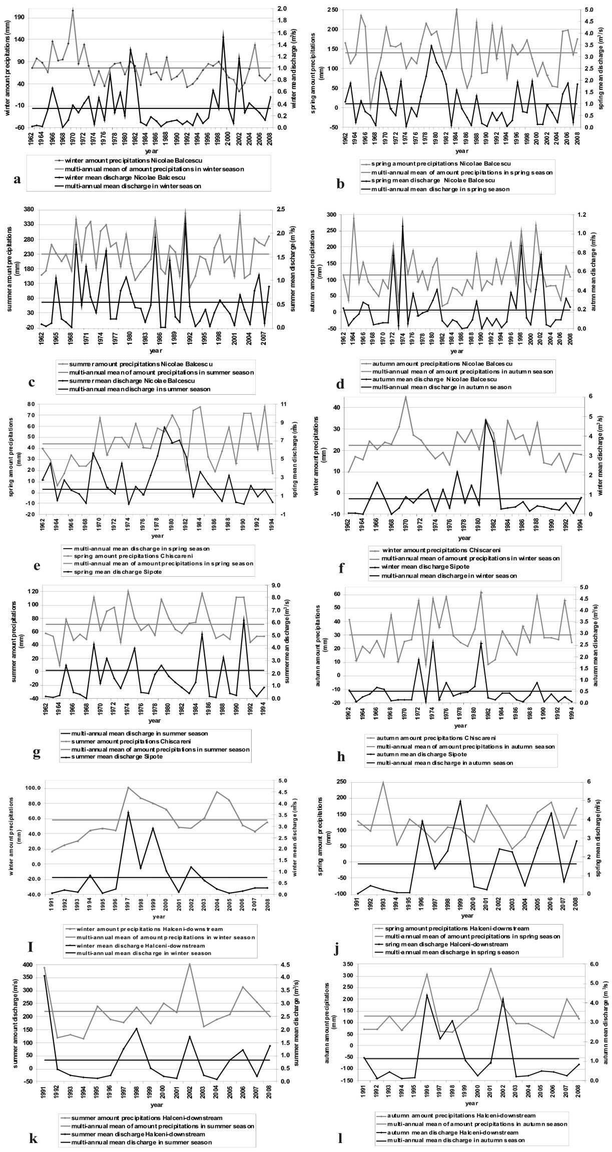

Fig. 4 - Multiannual variation of the annual precipitation amounts (mm) and of the liquid discharges (m^3/s), at Nicolae Balcescu, in the winter (a), spring (b), summer (c) and autumn (d) (1962–2008); Multiannual variation of the annual precipitation amounts (mm) at Chiscareni, and of the liquid discharges (m^3/s) at Sipote, in the winter (e), spring (f), summer (g) and autumn (h) (1962–1994); Multiannual variation of the annual precipitation amounts (mm) and of the liquid discharges (m^3/s), at Halceni–downstream, in the winter (i), spring (j), summer (k) and autumn (l) (1991–2008).

Tab. 9 - Means of module coefficients and of the seasonal precipitation amounts, in the spring, the summer, and the autumn, at the hydrometric station of Şipote and the rainfall station of Chiscareni Miletin (1962–1994)

Season	Periods	K	Central value of K	Deviation	Means of the annual precipitation amounts (mm)	Multiannual means of the annual precipitation amounts (mm)	Deviation
Spring	1962–1976	0.97	1	Negative	110	132.3	Negative
	1977–1982	2.5		Positive	151.1		Positive
	1983–1994	0.4		Negative	150.8		Positive
Summer	1962–1968	0.9	1	Negative	150.6	211.9	Negative
	1969–1991	1.5		Positive	238.4		Positive
	1992–1994	0.5		Negative	151.2		Negative
Autumn	1962–1971	0.55	1	Negative	71.6	90.2	Negative
	1972–1981	1.85		Positive	115.8		Positive
	1982–1995	0.5		Negative	85.6		Negative

Tab. 10 - Means of module coefficients and of the seasonal precipitation amounts, in the spring, the summer, and the autumn, at Halceni (1962–1994)

Season	Periods	K	Central value of K	Deviation	Means of the annual precipitation amounts (mm)	Multiannual means of the annual precipitation amounts (mm)	Deviation
Spring	1991–1995	0.1	1	Negative	131.9	116.6	Positive
	1996–1999	1.9		Positive	102.3		Negative
	2000–2004	0.7		Negative	94.3		Negative
	2005–2008	1.6		Positive	146.8		Positive
Summer	1991	4.8	1	Positive	324.4	198.1	Positive
	1992–2008	0.77		Negative	190.6		Negative
Autumn	1991–1995	0.4	1	Negative	92.7	126.1	Negative
	1996–2002	2		Positive	171		Positive
	2003–2008	0.4		Negative	111.5		Negative

The years characterized by discharges below the multiannual mean at Nicolae Balcescu recorded values of the precipitations amounts below the multiannual mean in over 50% of the cases in the winter, in over 60% of the cases in the spring, and between 80 and 90% of the cases in the summer and the autumn. Furthermore, there is over 60% chance in the winter and in the spring, and over 80% during the summer and the autumn for rich discharges in the years with seasonal precipitation amounts above the multiannual means (Fig. 4a,b,c,d,e,f,g,h,i,j,k,l; Table 11).

There are close correlations between the annual amounts of precipitations and the mean liquid discharges at Nicolae Balcescu, at Sipote, respectively, compared to Halceni–downstream, given the regulation of the Miletin waters downstream from Lake Halceni (Tables 8, 9, 10). In over 60% of the cases, in the period 1950–2008, the seasonal module coefficients had values below 1. In consequence, the probability of mean seasonal discharges over the multiannual mean is below 40%. Spring is the season with the highest probability of rich discharges at the stations of Nicolae Balcescu and Sipote because of the more abundant precipitations during this season and of the increase in the temperature, which determine the meltdown of snows. In autumn, the precipitation amounts decrease, while the probability of very low liquid discharges is the highest (Tables 12, 13).

Tab. 11 - The percentage values of the number of years with precipitations amounts and mean liquid discharges above the multiannual means and of the number of years with precipitations amounts and mean liquid discharges below the multiannual means in the four seasons at Nicolae Balcescu, Sipote, and Halceni–downstream

Observation point	Years with precipitation amounts and discharges over the multiannual mean (mm)				Years with precipitation amounts and discharges below the multiannual mean (mm)			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Nicolae Balcescu	56.25	68.42	82.35	82.35	67.74	67.86	80.00	86.67
Sipote	66.67	57.14	83.33	77.78	60.87	68.42	85.71	79.17
Halceni–downstream	66.67	37.50	66.67	40.00	75.00	60.00	75.00	69.00

Tab. 12 - Years with very low seasonal runoff at the stations of Nicolae Balcescu and Sipote (1950–2008)

Seasons	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
	Number of years				%			
Nicolae Balcescu	37.0	36.0	40.0	41.0	62.7	61.0	67.8	69.5
Sipote	41.0	36.0	38.0	43.0	69.5	61.0	64.4	72.9

Tab. 13 - Years with rich seasonal runoff at the station of Nicolae Balcescu and Sipote (1950–2008)

Seasons	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
	Number of years				%			
Nicolae Balcescu	22.0	23.0	19.0	18.0	37.3	39.0	32.2	30.5
Sipote	18.0	23.0	21.0	16.0	30.5	39.0	35.6	27.1

In order to determine the cyclic character of runoff in the four seasons, for the three rainfall stations, moving averages were calculated every ten years, staggered by one year. The graphic representation of the results underlines a period of increase in the runoff of the Miletin River in the winter, from 1950–1959 to 1973–1982. Following this period, the values of the module coefficient dropped dramatically until the period 1984–1993. Starting with 1984–1993, the discharges had an increasing trend until 1997–2006, and then the values dropped again.

The increase in the values of spring mean discharges was obvious in the period 1951–1960—1973–1986. After this period and until 1986–1985, the mean seasonal runoff dropped significantly. Currently, the general trend is ascending at all three rainfall stations.

In the summer, after a much accentuated increase in the values of moving averages, from 1959–1968 to 1969–1978, there was a long period of decrease in the discharges on the Miletin River until 1992–2001. At Nicolae Balcescu, after 1992–2001, there has been an accentuated increasing trend of the discharges. In the past few years, at the hydrometric stations of Sipote at Halceni–downstream, the runoff has recorded ever-lower values.

Tab. 14 - Means of seasonal module coefficients and means of seasonal precipitation amounts in the periods with maximum runoff values (1962–2008)

A	Hydrometric station of	Periods with the highest positive deviations (m^3/s)	K	Central value of K	Deviation	Rainfall stations	Precipitations in the period with the highest positive deviations (mm)	Mean multiannual precipitations (mm)	Deviation
W	Nicolae Balcescu	1973–1982	1.77	1	Positive	Nicolae Balcescu	72.4	70.7	Positive
		1997–2006	1.71		Positive		77.1		Positive
	Sipote	1973–1982	1.97		Positive	Chiscareni	70.2	66.7	Positive
	Halceni–downstream	1996–1985	1.62		Positive	Halceni	63.2	57.8	Positive
Sp	Nicolae Balcescu	1973–1982	1.90	1	Positive	Nicolae Balcescu	151.5	149.8	Positive
	Sipote	1973–1982	1.85		Positive	Chiscareni	149.9	132.3	Positive
	Halceni–downstream	1997–2006	1.29		Positive	Halceni	109.1	116	Negative
Su	Nicolae Balcescu	1969–1978	1.69	1	Positive	Nicolae Balcescu	274.2	231	Positive
	Sipote	1969–1978	1.68		Positive	Chiscareni	238.8	211.9	Positive
	Halceni–downstream	1991–2000	0.98		Positive	Halceni	202.5	220.7	Negative
S	Nicolae Balcescu	1972–1981	1.90	1	Positive	Nicolae Balcescu	135.8	113.2	Positive
		1993–2002	1.62		Positive	Nicolae Balcescu	151.7		Positive
	Sipote	1972–1981	1.85		Positive	Chiscareni	115.8	90.9	Positive
	Halceni–downstream	1996–2005			Positive	Halceni	145.3	126.1	Positive

S-Season; W-Winter; Sp-Spring; Su-Summer; A-Autumn.

In the autumn, in the period 1950–2008, it is worth mentioning two increasing intervals of runoff values (1962–1971—1972–1981, 1986–1995—1993–2002, respectively) and two intervals with a decreasing trend in the discharges (1950–1959–1961–1970 and 1994–2003 to the present) (Fig. 5a,b,c,d).

The periods with the most significant positive deviations of the mean runoff, at the stations of Nicolae Balcescu, Sipote, respectively, were characterized by significant amounts of precipitations during all the four seasons. The lowest means of seasonal module coefficients, calculated on 10-year periods, represent a consequence of negative deviations of the annual precipitation amounts, for the stations with natural runoff. At Halceni–downstream, the stream regulation determines weak correlations between the means of seasonal module coefficients and the means of seasonal precipitation amounts calculated on 10-year periods (Tables 14, 15).

Tab. 15 - Means of seasonal module coefficients and means of seasonal precipitation amounts in the periods with minimum runoff values (1962–2008)

S	Hydrometric station of	Periods with the lowest positive deviations (m^3/s)	K	Central value of K	Deviation	Rainfall stations	Precipitations in the period with the lowest positive deviations (mm)	Mean multiannual precipitation (mm)	Deviation
W	Nicolae Balcescu	1984–1993	0.29		Negative	Nicolae Balcescu	63.5	75.7	Negative
	Sipote	1984–1993	0.38	1	Negative	Chiscareni	63.4	66.7	Negative
	Halceni–downstream	1999–2008	0.93		Negative	Halceni	63.8	57.8	Positive
Sp	Nicolae Balcescu	1986–1995	0.45		Negative	Nicolae Balcescu	130.2	149.8	Negative
	Sipote	1986–1995	0.48	1	Negative	Chiscareni	No data available	No data available	No data available
	Halceni–downstream	1991–2000	0.84		Negative	Halceni	110.1	116.0	Negative
Su	Nicolae Balcescu	1992–2001	0.56		Negative	Nicolae Balcescu	199.4	231.0	Negative
	Sipote	1992–2001	0.65	1	Negative	Chiscareni	No data available	No data available	No data available
	Halceni–downstream	1992–2001	0.64		Negative	Halceni	185.3	220.7	Negative
A	Nicolae Balcescu	1986–1995	0.39		Negative	Nicolae Balcescu	105.4	113.2	Negative
	Sipote	1986–1995	0.45	1	Negative	Chiscareni	No data available	No data available	No data available
	Halceni–downstream	1999–2008	0.77		Negative	Halceni	137.8	126.1	Positive

S-Season; W-Winter; Sp-Spring; Su-Summer; A-Autumn.

The moving averages underline certain periods in the fluctuation of the seasonal multiannual runoff: in the winter, from 1950–1959 to 1984–1993 (35 years), in the spring, from 1951–1960 to 1986–1995 (35 years), in the summer, in the interval 1959–1968–1992–2001 (33 years), and in the autumn, with a 30-year variation period (1956–1965 — 1986–1995). The correlation between the variations of the mean seasonal discharges at the stations of Nicolae Balcescu and Sipote was very close in the period 1950–1959 — 1980–1989. After 1990–1999, Pearson's correlation coefficient presents ever-lower values, mostly during the autumn and the winter. The cause of the ever-weaker synchronization of the seasonal runoff from the two observation points can be the – ever more important – impact of human activities on the environment (Fig. 6; Table 16). First, it is worth noting the use of water in traditional farming and for household purposes.

Conclusions

Within the basin of the Miletin River, there is a seasonal distribution of discharges, specific to the rivers in the transitional temperate climate. The richest runoff is recorded in the spring, because of snow meltdown and of the increase in the amount of precipitations. The discharge values begin dropping until the first half of autumn. In the winter, warm-up periods interrupt the continuity of the snow layer, reason for which there is an increase in the liquid runoff. The alternation of periods with high and low discharges, between 1950 and 2008, for the three rainfall stations in the Miletin River basin, overlaps partially during all the four seasons. The distribution of these periods is not equal in time.

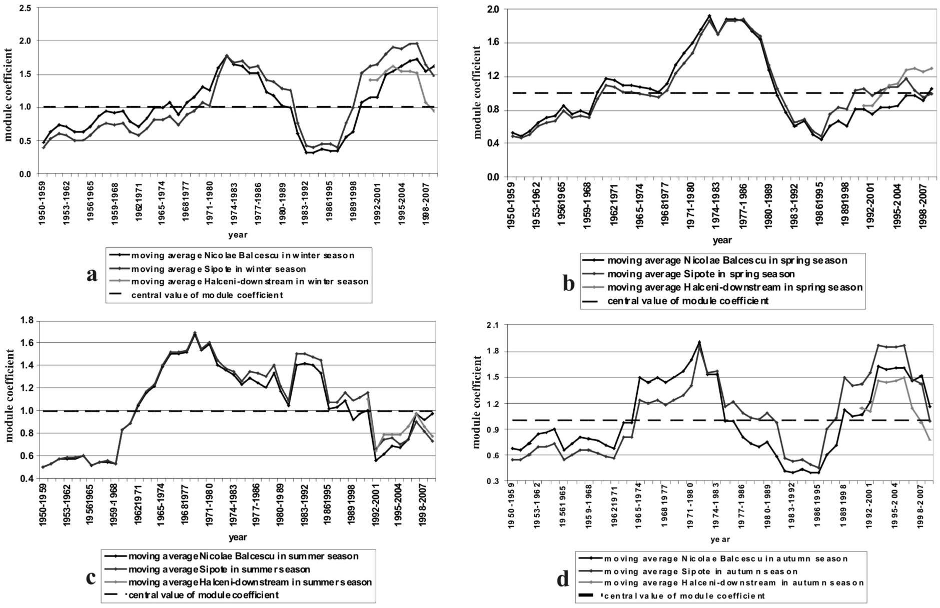

Fig. 5 - a.Evolution of module coefficients, calculated with moving averages every 10 years, staggered by a year in the winter, spring, summer and autumn, in the Miletin hydrographic basin (1950–2008)

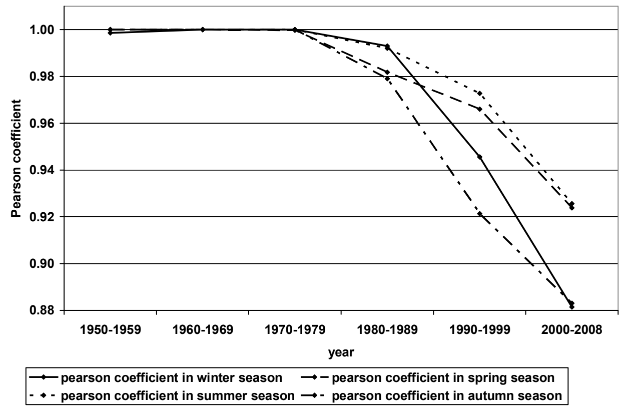

Fig. 6 - Seasonal variation of Pearson's correlation coefficient that characterizes the liquid discharges at the rainfall stations with natural runoff (Nicolae Balcescu and Sipote), in the Miletin River basin, in the period 1950–2008

Tab. 18 - Seasonal values of Pearson's correlation coefficient between the stations of Nicolae Balcescu and Sipote

Periods	r_{winter}	r_{spring}	r_{summer}	r_{autumn}
1950–1959	0.99	1.00	1.00	1.00
1960–1969	1.00	1.00	1.00	1.00
1970–1979	1.00	1.00	1.00	1.00
1980–1989	0.99	0.98	0.99	0.97
1990–1999	0.94	0.96	0.97	0.92
2000–2008	0.88	0.92	0.92	0.88

The rainfall deficit what characterizes the climate in the east of the Carpathian Mountains determines a high frequency of discharges with negative deviations from the multiannual mean in the winter, the summer, and the autumn. The probability of mean seasonal discharges exceeding the multiannual mean is lower (under 50%). Spring is the season with the highest probability of rich discharges at the stations of Nicolae Balcescu and Sipote because of the precipitations falling during this season and of the increases in the temperature, which determine the snow meltdown.

The moving averages underline certain periods of 30–35 years, in the seasonal multiannual runoff fluctuation. It is not certain whether this represents a rhythmic segment of a multi-secular variation. The brief data rows represent an impediment in the emphasis on the cyclic character concerning the multiannual runoff variation.

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References

Calinescu G., Calinescu N., Soare E. (1997), *Caracteristici şi tendinţe ale precipitaţiilor maxime cazute in diferite intervale de timpi in Moldova*, Proceedings of the "Dimitrie Cantemir" Geographic Seminar, 13-14: 25-32.

Cigizoglu H.K., Bayazit M., Onoz B. (2005), *Trends in the Maximum, Mean, and Low Flows of Turkish Rivers*, Journal of Hydrometeorology, 6: 280-290.

Dettinger M.D., Diaz H.F. (2000), *Global Characteristics of Stream Flow Seasonality and Variability*, Journal of Hydrometeorology, 1(8): 289-310.

Machado F., Mine M., Kaviski E., Fill H. (2011), *Monthly rainfall-runoff modelling using artificial neutral networks*, Hydrological Sciences Journal, 56(3): 349-361.

McCuen R.H., Beighley R.E. (2003), *Seasonal flow frequency analysis*, Journal of Hydrology, 279(1): 43-56.

McKerchar A.I., Pearson C.P. (1994), *Forecasts of seasonal river flows using southern oscillation index*, Journal of Hydrology (NZ), 32(2): 16-29.

Pantazica M., Schram M. (1967), *Contribuţii la cunoaşterea hidrologica a bazinului raului Miletin*, Hydrobiology, 253-262

Parajka J., Kohonova S., Merz R., Szolgay J., Hlavčová K., Blösche G. (2009), *Comparative analysis of the seasonality of hydrological characteristics in Slovakia and Austria*, Hydrological Sciences Journal, 54(3): 456-473.

Pilling C.G., Jones J.A.A. (2002), *The impact of future climate change on seasonal discharge, hydrological processes and extreme flows in the Upper Wye experimental catchment, Mid-Wales*, Hydrological Processes, 16(6): 1201-1213.

Romanescu G. (2009), *Siret river basin planning (Romania) and the role of wetlands in diminishing the floods*, WIT Transaction on Ecology and the Environment, 125: 439-453.

Romanescu G., Cojocaru I. (2010), *Hydrogeological considerations on the western sector of the Danube Delta – a case study for the Caraorman and Saraturile fluvial-marine levees (with similarities for the Letea levee)*, Environmental Engineering and Management Journal, 9(6): 795-806.

Romanescu G., Jora I., Stoleriu C. (2011), *The most important high floods in Vaslui river basin – causes and consequences*, Carpathian Journal of Earth and Environmental Sciences, 6(1): 119-132.

Romanescu G., Nistor I. (2011), *The effect of the July 2005 catastrophic inundations in the Siret River's Lower Watershed, Romania*, Natural Hazards, 57(2): 345-368.

Romanescu G., Stoleriu C., Romanescu A.M. (2011a), *Water reservoirs and the risk of accidental flood occurrence. Case study: Stanca–Costesti reservoir and the historical* *floods of the Prut river in the period July–August 2008, Romania*, Hydrological Processes, 25(13): 2056-2070.

Romanescu G., Stoleriu C., Zaharia C. (2011b), *Territorial Repartition and Ecological Importance of Wetlands in Moldova (Romania)*, Journal of Environmental Science and Engineering, 5(11): 1435-1444.

Romanescu G., Zaharia C., Stoleriu C. (2012a), *Long-term changes in average annual liquid flow river Miletin (Moldavian Plain)*, Carpathian Journal of Earth and Environmental Sciences, 7(1): 161-170.

Romanescu G., Cotiuga V., Asandulesei A., Stoleriu C. (2012b), *Use of the 3-D scanner in mapping and monitoring the dynamic degradation of soils. Case study of the Cucuteni-Baiceni Gully on the Moldavian Plateau (Romania)*, Hydrology and Earth System Sciences, 16: 953-966.

Silva A.T., Portela M.M. (2012), *Disaggregation modelling of monthly streamflow using a new approach of the method of fragments*, Hydrological Sciences Journal, 57(5): 942-955.

Villarini G., Smith J.A., Serinaldi F., Ntelekos A.A. (2010), *Analysis of seasonal and annual maximum daily discharge records for central Europe*, Journal of Hydrology, 399(3-4): 299-312.

Vinogradov Y.B., Semenova O.M., Vinogradova T.A. (2010), *An approach to the scaling problem in hydrological modelling the deterministic modelling hydrological system*, Hydrological Processes, 25: 1055-1073.