ASPECTS REGARDING THE TREND OF THE AVERAGE ANNUAL, SEASONAL AND MONTHLY DRAINAGE OF RIVER WATER FROM THE CĂLIMAN MOUNTAINS IN THE PERIOD 1950-2010

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Abstract: Aspects regarding the trend of the average annual, seasonal and monthly drainage of river water from the Căliman Mountains in the period 1950-2010. The Căliman Mountains are the highest volcanic mountains in Romania, being positioned on the western side of the Eastern Carpathians, between their central strip (north and east), south – the Harghita Mountains, and west – the Transylvanian Depression. This positioning gives special features of the water drainage, with both spatial and temporal differentiations. This paper analyzed the trend of average drainage from rivers in the studied group for the period 1950-2010, both multi-annually and seasonally and in the extreme months; the months taken into account being those with the lowest flows (January), respectively the largest (May). To evaluate the mentioned parameters, we used the help of Excel MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), which identified the type of drainage trend (positive or negative), and using the Sen nonparametric method to estimate the slope of the trend. Based on the type of trend obtained, 9 trend classes were obtained, and with the help of the slope, the net change rate was obtained.

Keywords: Căliman Mountains, drainage, Mann-Kendall, trend, slope.

INTRODUCTION

The Căliman Mountains in the Eastern Carpathians are a special area due to its morphology, geology and positioning in the space of the Carpathian chain (Fig. 1). The high altitude (over 2000 m), the positioning at the exit of the Eastern Carpathians and the massiveness given by the volcanic substrate, make it a source of rivers with a rich flow and a radial flow, belonging to three large river basins and a barrier important against western and eastern air masses. This is manifested in the regime of runoff and in its variation and trend in time and space, with differentiations between runoff on slopes with different orientations.

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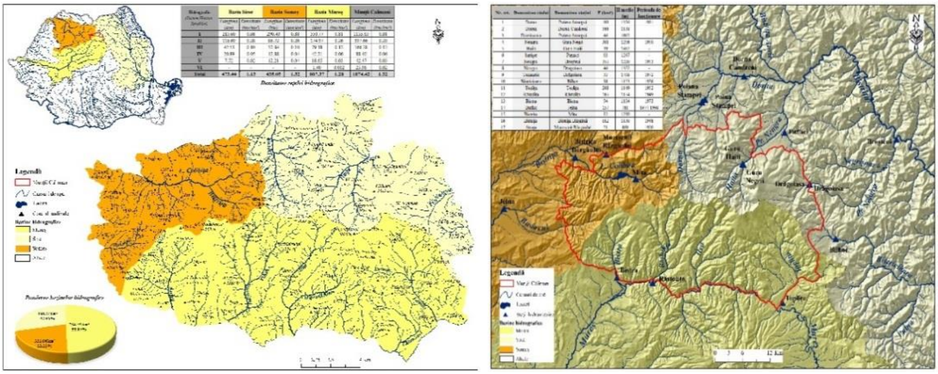

Fig. 1. The Căliman Mountains and the hydrological stations related to them

DATA BASE AND METHOD

For the elaboration of this article, average hydrological data at the hydrological stations from the Căliman Mountains were used. In order to better represent the space and to have higher flow values that are not so easily influenced by meteorological phenomena, for the analysis were taken into account 4 hydrological stations with natural flow, representative, located at the edge of the area analyzed, two located at the contact with the central strip of the Eastern Carpathians (Poiana Stampei and Bilbor), mostly inside the mountains, and two located more on the periphery (Răstolița and Mița). These stations were chosen with an approximately equal basin area and similar altitudes for a presentation of the drainage situation on all sides of the analyzed mountain group.

These are presented in Table 1. the data were obtained from the Regional Water Branches: Siret Branch – Bacău, Mureș Branch – Târgu Mureș and Someș Branch – Cluj-Napoca.

Table 1. Hydrological stations in the Căliman Mountains taken into analysis

River	**Hydro. Station**	**Hydr. Basin**	**Position in basin**	**Basin surface (km^2)**	**Basin altit. (m)**	**Q med (m^3/s)**	**Q max (m^3/s)**	**Q min (m^3/s)**
Dorna	Poiana Stampei	Siret	N	100	1376	2,33	4,04	0,40
Bistricioara	Bilbor	Siret	E	100	1376	0,96	1,60	0,36
Răstolița	Răstolița	Mureș	S	163	1174	3,49	6,15	1,61
Bistrița Ardeal.	Mița	Someș	V	82	1230	0,92	3,24	0,06

For a better and brief representation of the meteorological variation, two stations were taken into account - Rețitiș stations and Bistrița station, the first located at altitude (over 1300 m), and the other at 800 m. The data come from the National Meteorological Administration of Romania.

The method used in the paper to calculate the average leakage trend was the Mann-Kendall test, used using the Excel MAKESENS application (Mann-Kendall test for trend and Sen's slope estimates), created by researchers at the Finnish Institute of Meteorology. The application of the non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1975) allowed the identification of the type of trend (positive or negative), and the nonparametric method Sen's (Gilbert, 1987) allows the estimation of the slope of the trend (Salmi et all., 2002).

„The Mann-Kendall test is applicable in cases when the data values xi of a time series can be assumed to obey the model

$$xi = f(t) + \varepsilon_i \quad (1)$$

where f (t) is a continuous monotonic function increasing or decreasing with time and residues ε_i. (…)

It can be assumed that they are from the same distribution with zero average. Therefore, the variance of the distribution is assumed to be constant over time.

In the calculation of this statistical test MAKESENS exploits both the so-called S statistics given in Gilbert (1987) and the normal approximation (Z statistics). For time series with less than 10 data points the S test is used, and for time series with 10 or more data points the normal approximation is used.

If n is at least 10, the normal approximation test is used. However, if there are multiple bound values (ie. equal values) in the time series, it may reduce the validity of the normal approximation when the number of data values is close to 10.

The presence of a statistically significant trend is assessed using the Z value. A positive (negative) value of Z indicates an upward (downward) trend. The Z value has a normal distribution. To test either a monotonous upward or downward trend (a two-tailed test) at the significance level α, H0 is rejected if the absolute value of Z is greater than Z1-α / 2, whence Z1-α / 2 is obtained from the normal standard tables of cumulative distribution. In MAKESENS, the significance levels tested α are 0.001, 0.01, 0.05 and 0.1.

In order to estimate the true slope of an existing trend (as a change per year), Sen's nonparametric method is used. The Sen Method can be used in cases where the trend can be assumed to be linear. This means that f (t) is equal to

$$f(t) = Qt + B$$

where Q is the slope and B is a constant. Q is the true slope of the linear trend, ie the change per unit of time" (after Salmi et all., 2002)

For the analysis of the average annual, seasonal and monthly trends, both the interval 1950-2010 and the decadal intervals of 10 years were taken into account, where the Sen method can be used, thus identifying the general trend of the average flow at the level of the whole period and decadal, as well as the value.

With the help of the Excel MAKESENS program we obtained the absolute value of Z which defines whether or not there is a trend at the selected level α of significance. A positive (negative) Z value indicates an upward (downward) trend. The Sen slope (Q) is the true slope of the linear trend (Z), ie the change per unit period of time. Based on the slope Q (mm / year) the net change rate was calculated (R, in %):

$$R = Q * 10 / Qr * 100,$$

where Qr is the river flow for the analyzed period.

Also, a qualitative assessment of the values of the Z slope was made, through a detailed analysis of the ranges of values obtained which correspond to four classes for increasing trends and four for decreasing, a class belonging to the stationary type (Table 2).

***Table 2**. Qualifications and value thresholds used to analyze the trend of water flow in the rivers Căliman Mountains (after Porcuțan, Adriana, 2018)*

increase		**Decrease**	
Qualifying	**Value threshold**	**Qualifying**	**Value threshold**
II intense increase	> 5,0	ID intense decrease	< -5
PI pronounced increase	3,01 … 5,0	PD pronounced decrease	-5,0 …'-3,01
MI moderate increase	1,51 ... 3,0	MD moderate decrease	-3,0 …'-1.51
SI slight increase	0,51 … 1,5	SD slight decrease	-1,5 … -0,51
S Stationary:	0.50........0,50		

The analysis of the average drainage trend was done annually, as well as seasonally and for the extreme months, these being for the study area January and May. Also, for an analysis of the variability of the flow over time, an analysis of the flow trend in the six decades between 1950 and 2010 was performed.

RESULTS AND DISCUSSIONS

In the period 1950-2010 a general trend can be observed that varied from one side to another of the analyzed group, the stations belonging to the Siret river basin showing increases (Bilbor, from the east – accentuated increase, Poiana Stampei, from the north - slight increase), while the stations Mița, which belongs to the Someș river basin, from the west, and Răstolița, positioned to the south in the Mureș river basin, a slight decreasing trend (Table 3).

Table 3. Average annual runoff trend for the period 1950-2010, with trend ratings and net change rate values (NCR, in %)

1950-2010	Slope parameters	Hydrometric station			
		Poiana Stampei	Bilbor	Răstolița	Mița
Annual	Sens	**SI**	**PI**	**SD**	**SD**
	NCR (%)	2,19	6,38	-0,89	-2,17
Winter	Sens	**SI**	**MI**	**S**	**MD**
	NCR (%)	5,62	4,52	0,05	-10,00
Spring	Sens	**S**	**MI**	**SD**	**S**
	NCR (%)	1,12	4,69	-2,76	0,15
Summer	Sens	**S**	**MI**	**SD**	**SD**
	NCR (%)	0,00	3,83	-2,40	-3,39
Autumn	Sens	**SI**	**MI**	**MI**	**SI**
	NCR (%)	6,15	10,73	5,92	5,92
January	Sens	**MI**	**MI**	**SI**	**MD**
	NCR (%)	8,66	2,37	3,51	-5,94
May	Sens	**S**	**S**	**SD**	**SI**
	NCR (%)	-0,06	-2,47	-3,11	3,12

At the seasonal level, the stations in the Siret River basin maintain the same increase trend, higher at Bilbor station, where it is in all seasons and in the extreme months a moderate increase (except May, when the trend is stationary), and at Poiana Stampei station there is a slight increase in winter and autumn (even moderate during January). Răstolița station in the south shows a stationary trend, respectively a slight increase for winter, respectively moderate for autumn, and a slight decrease for the rest of the periods. At the Mita station, there is a decreasing trend the flow during winter and autumn, respectively of moderate decrease during January and of slight increase in May.

The lowest values of the net change rate were registered for Răstolița station during May, with a value of -3.11%, and the highest for Bilbor station of 10.73% during autumn, the season in which records also the highest values of the net change rate in the Căliman Mountains (Fig 2).

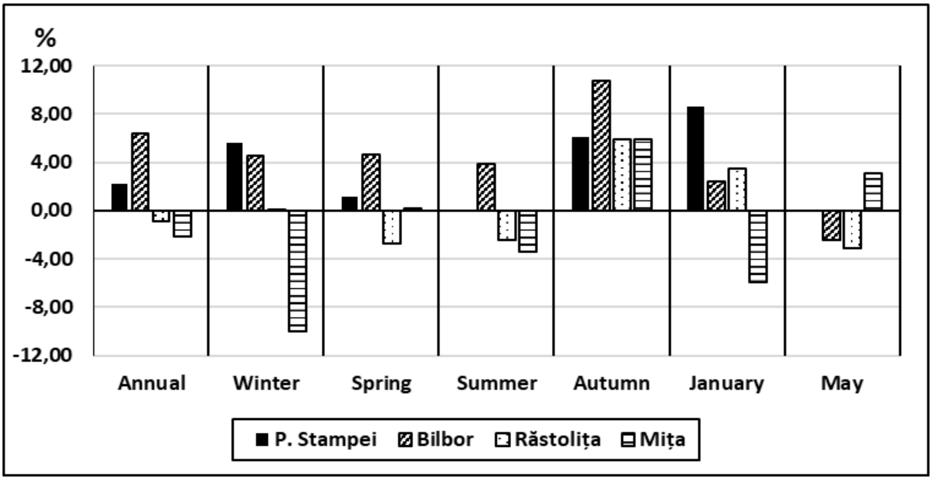

Fig. 2. Net change rate (%) in the period 1950-2010, annually, seasonally and in extreme months

The decade **1950-1960** presented at an annual level a generalized increasing trend throughout the period, with the highest rates at the stations positioned in the south and west (74.79% at Mita). Similar increasing trends are registered in winter and spring, while in summer and autumn there are differences between the stations in the Siret River basin and the other stations, the first being stationary and the other increase (Table 4).

Table 4. Average annual runoff trend for the period 1950-1960, with trend ratings and net change rate values (NCR, in %)

1950-1960	Slope parameters	Hydrometric station			
		Poiana Stampei	Bilbor	Răstolița	Mița
Annual	Sens	**SI**	**SI**	**MI**	**MI**
	NCR (%)	17,88	17,60	56,85	74,79
Winter	Sens	**SI**	**SI**	**MI**	**MI**
	NCR (%)	66,62	34,32	73,63	61,31
Spring	Sens	**SI**	**SI**	**SI**	**SI**
	NCR (%)	38,25	45,55	44,13	46,01
Summer	Sens	**S**	**S**	**SI**	**MI**
	NCR (%)	-0,06	21,31	68,26	119,11
Autumn	Sens	**S**	**S**	**MI**	**SI**
	NCR (%)	5,61	-1,80	65,61	93,83
January	Sens	**S**	**S**	**S**	**SI**
	NCR (%)	17,33	38,60	21,16	70,93
May	Sens	**SI**	**SI**	**MI**	**MI**
	NCR (%)	66,23	91,55	140,98	64,26

The lowest values of the rate are at Bilbor station during autumn, while the highest values are recorded during May at Răstolița station, when it exceeds 100% (140.98%).

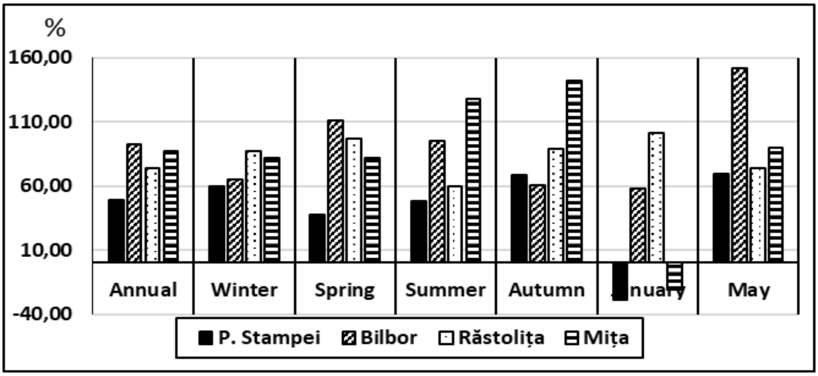

Fig. 3. Net change rate (%) in the period 1950-1960, annually, seasonally and in extreme months

During the decade **1961-1970**, the trend of moderate increase is maintained annually, becoming even more pronounced at Bilbor station. The same increasing trend is maintained at seasonal and monthly level, the only exception being January at Poiana Stampei station, where there is a slight decreasing trend, at Mita station the trend is stationary.

Table 5. Average annual runoff trend for the period 1960-1970, with trend ratings and net change rate values (NCR, in %)

1961-1970	Slope parameters	Hydrometric station			
		Poiana Stampei	Bilbor	Răstolița	Mița
Annual	Sens	**SI**	**PI**	**MI**	**MI**
	NCR (%)	48,77	92,19	73,88	87,10
Winter	Sens	**SI**	**MI**	**MI**	**MI**
	NCR (%)	59,35	64,66	87,38	81,99
Spring	Sens	**SI**	**MI**	**MI**	**MI**
	NCR (%)	37,43	111,07	96,92	82,09
Summer	Sens	**MI**	**MI**	**SI**	**MI**
	NCR (%)	47,79	95,22	60,05	127,53
Autumn	Sens	**SI**	**MI**	**MI**	**MI**
	NCR (%)	68,43	60,13	88,48	142,03
January	Sens	**SD**	**MI**	**SI**	**S**
	NCR (%)	-29,07	57,52	101,66	-21,11
May	Sens	**MI**	**MI**	**MI**	**MI**
	NCR (%)	69,69	151,45	74,00	89,63

The values of the net change rate are mostly positive, the only negative ones appearing in January at Poiana Stampei and Mița stations. It can be seen that the highest values appear at the stations located in Transylvania, especially Mita, where the abundant rainfall in May 1970 and the resulting floods, continued with a rainy year throughout Transylvania, strongly influenced the results, the highest monthly values being recorded in autumn at Mita (Fig. 3).

The same increasing trend (slight increase) at the annual level, slightly more faded than in previous decades, is maintained in the decade **1971-1980**, with small variations.

At the seasonal level, stationary - slightly decreasing trends appear in winter (respectively January) and summer, while during the autumn there is a slight increase, during the spring appearing the largest increases (moderate increases).

Table 6. Average annual flow trend for the period 1971-1980, with trend ratings and net change rate values (NCR, in %)

1971-1980	**Slope parameters**	**Hydrometric station**			
		Poiana Stampei	**Bilbor**	**Răstolița**	**Mița**
Annual	Sens	**SI**	**SI**	**SI**	**SI**
	NCR (%)	36,12	18,49	33,13	27,31
Winter	Sens	**SD**	**S**	**S**	**S**
	NCR (%)	-22,83	28,57	7,44	-13,84
Spring	Sens	**MI**	**MI**	**MI**	**MI**
	NCR (%)	57,05	74,31	51,34	57,24
Summer	Sens	**S**	**SD**	**SD**	**S**
	NCR (%)	14,60	-32,16	-8,04	14,72
Autumn	Sens	**SI**	**SI**	**S**	**S**
	NCR (%)	40,90	31,70	27,70	34,44
January	Sens	**S**	**S**	**S**	**SD**
	NCR (%)	-26,00	7,89	-4,48	-34,10
May	Sens	**MI**	**SI**	**SI**	**MI**
	NCR (%)	87,97	48,71	57,42	57,10

The net rate values are the lowest during January, reaching values of -26.0% at Poiana Stampei station and -34.44% at Mița station. The highest values are recorded during the spring at all stations, the maximums exceeding 80%, being reached at Poiana Stampei stations (87.97% - May).

This general upward trend in the period 1950-1980 can be attributed to the general increasing trend of precipitation during this period in the entire Căliman Mountains, a trend that was corroborated with a relatively constant maintenance of temperatures during this period. This precipitation trend is shown in Fig. 4. In the following period, the amounts of precipitation decreased as a quantity, increasing only towards the end of the interval, in the years 2004-2010.

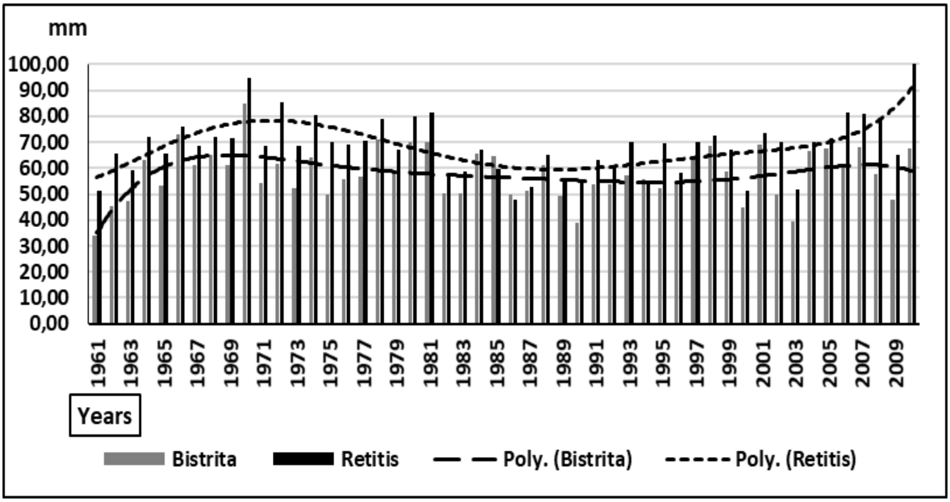

Fig. 4. The multiannual variation and the precipitation trend at Rețitiș and Bistrița stations

As a result, the decade **1981-1990** shows a general decreasing trend, even of moderate decrease at Bilbor station, located to the east, deep inside the mountains (Table 7). This trend is most accentuated for the spring and summer seasons, in the rest of the seasons it is predominantly stationary; the most negative values being registered during the summer, the month of May also presenting very negative values.

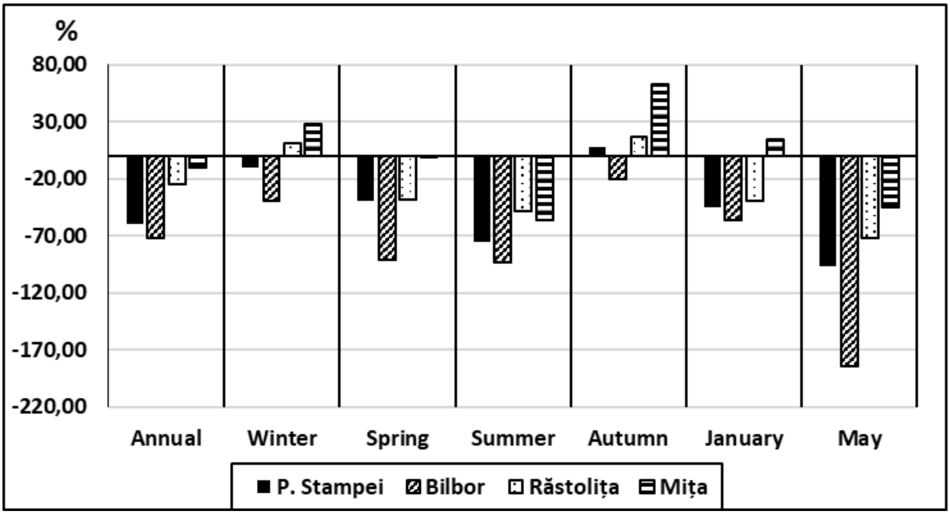

Fig. 5. Net change rate (%) during 1981-1990, annually, seasonally and in extreme months

The lowest values of the seasonal rate were registered in the east, at Bilbor station (-93.09% during the summer, -183.85% for May), being the only station where no positive values of trend throughout the period. Values increase from south and west, the highest being recorded at Mita station (62.55% during autumn) (Fig. 5).

This decadal situation, completely different from that of previous decades, was due to the strong meteorological and hydrological drought recorded in the middle of this period (Fig. 5), more strongly felt inside the mountain range, as evidenced by the fact that the lowest values were recorded at the stations deepest inside the Eastern Carpathians - Poiana Stampei and Bilbor stations, while Răstolița and Mița stations, located at the exit of the Carpathian chain, showed higher values of trends in all cases analyzed.

Table 7. Average annual runoff trend for the period 1981-1990, with trend ratings and net change rate values (NCR, in %)

1981-1990	Slope parameters	Hydrometric station			
		Poiana Stampei	Bilbor	Răstolița	Mița
Annual	Sens	**SD**	**MD**	**SD**	**S**
	NCR (%)	-59,91	-72,50	-24,88	-10,85
Winter	Sens	**S**	**SD**	**S**	**S**
	NCR (%)	-10,13	-39,79	11,29	28,28
Spring	Sens	**SD**	**MD**	**SD**	**S**
	NCR (%)	-39,68	-90,90	-37,92	-0,50
Summer	Sens	**MD**	**MD**	**MD**	**MD**
	NCR (%)	-74,89	-93,09	-48,20	-56,04
Autumn	Sens	**S**	**SD**	**SI**	**SI**
	NCR (%)	7,19	-20,47	17,00	62,55
January	Sens	**SD**	**SD**	**SD**	**S**
	NCR (%)	-45,58	-56,58	-39,93	14,04
May	Sens	**MD**	**MD**	**MD**	**SD**
	NCR (%)	-96,79	-183,85	-71,96	-44,58

In the decade **1991-2000**, the general drainage trend varies from one station to another, from a slight decrease at Răstolița station, to a moderate increase at Mița station (Table 8). Significant differences from the previous period occur over the seasons, with a slight and moderate increase in spring runoff, much needed to supply the water reserves of the soil dried in the periods 1980-1990. In the rest of the seasons, the trend is stationary and slightly decreasing, reaching even a moderate decrease at Răstolița station during autumn.

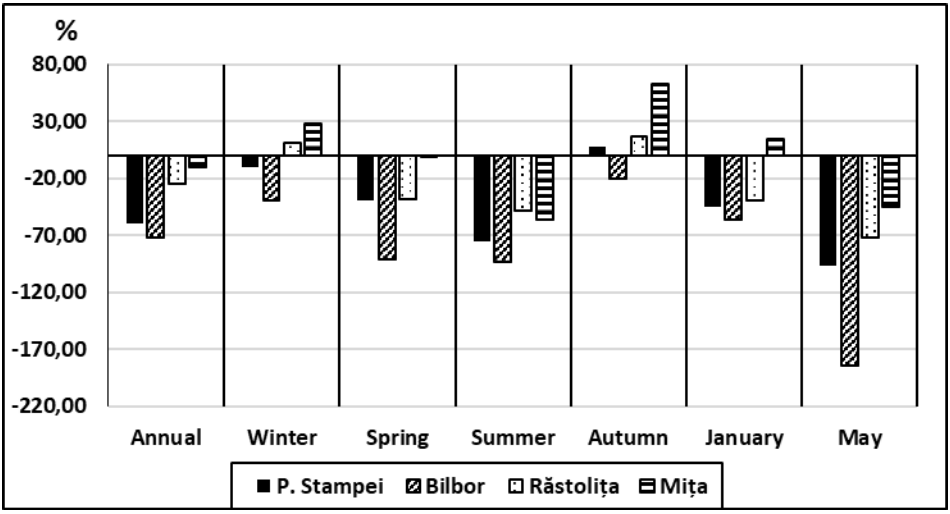

Table 8. Average annual runoff trend for the period 1991-2000, with trend ratings and net change rate values (NCR, in %)

1991-2000	Slope parameters	Hydrometric station			
		Poiana Stampei	Bilbor	Răstolița	Mița
Annual	Sens	**S**	**SI**	**SD**	**MI**
	NCR (%)	61,40	15,63	-23,01	40,33
Winter	Sens	**SD**	**S**	**SD**	**SI**
	NCR (%)	-18,71	-0,37	-69,26	42,76
Spring	Sens	**MI**	**SI**	**SI**	**MI**
	NCR (%)	117,67	51,83	35,10	52,01
Summer	Sens	**S**	**SD**	**SD**	**S**
	NCR (%)	11,49	-13,93	-30,48	-7,89
Autumn	Sens	**S**	**S**	**MD**	**S**
	NCR (%)	-6,43	-3,04	-81,36	17,79
January	Sens	**S**	**S**	**SD**	**S**
	NCR (%)	-47,15	6,58	-41,48	-5,79
May	Sens	**SI**	**S**	**SD**	**SD**
	NCR (%)	89,41	6,21	-45,00	-25,42

Table 9. Average annual runoff trend for the period 2001-2010, with trend ratings and net change rate values (NCR, in %)

2001-2010	Slope parameters	Hydrometric station			
		Poiana Stampei	**Bilbor**	**Răstolița**	**Mița**
Annual	Sens	**SD**	**SD**	**MI**	**S**
	NCR (%)	-16,63	-36,11	54,64	7,84
Winter	Sens	**S**	**SI**	**MI**	**SI**
	NCR (%)	11,46	75,43	64,97	60,28
Spring	Sens	**S**	**SI**	**SI**	**S**
	NCR (%)	6,86	19,02	64,29	26,35
Summer	Sens	**S**	**S**	**SI**	**S**
	NCR (%)	13,37	-26,37	38,05	42,71
Autumn	Sens	**MD**	**MD**	**S**	**SD**
	NCR (%)	-98,96	-120,83	10,43	-54,53
January	Sens	**S**	**SI**	**MI**	**SI**
	NCR (%)	11,43	38,82	60,28	58,02
May	Sens	**SI**	**S**	**SI**	**SI**
	NCR (%)	52,25	12,73	0,89	76,23

The lowest values of the net rate appear during autumn, with a minimum at Bilbor station during autumn (-120.83%) and with a maximum during winter at Răstolița station (64.97%) (Fig. 6).

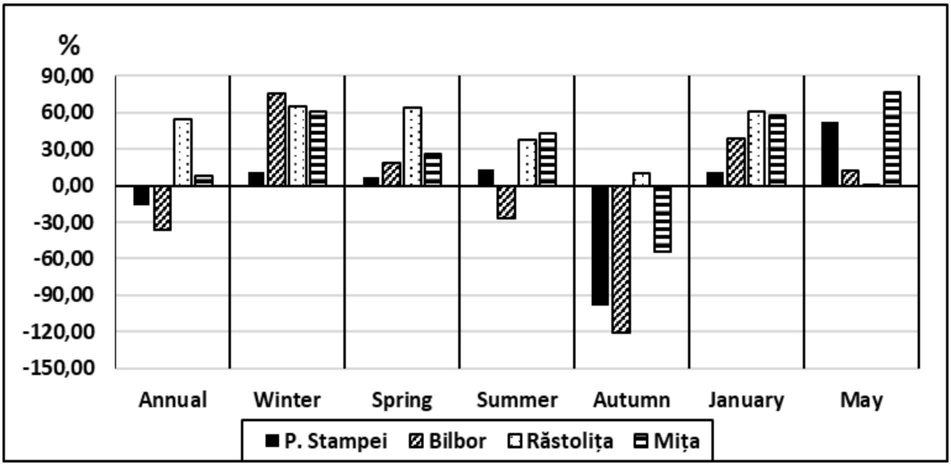

Fig. 6. Net change rate (%) in the period 2001-2010, annually, seasonally and in extreme months

CONCLUSIONS

The trend of average drainage in the period 1950-2010 varied greatly in time and space in the Căliman Mountains, showing a strong increase in the period 1950-1980, caused by rainy periods recorded especially in the '70s which was followed by a drastic decline in the decade. The 1980-1990 decade, which manifested itself through a period of severe drought throughout the country, as well as in the study area, especially in the middle of the period (1984 and 1985). This sharp decrease influenced the whole water flow further, returning to a steady increasing trend only towards the end of the period.

At the spatial level, the upward trend of the runoff was more accentuated at the western and southern stations, belonging to the Someș and Mureș River basins, located in contact with the Transylvanian depression sector, which is stationary with lower values in the Siret basin, at the stations inside mountain space.

At the seasonal level, a variation can be observed from a strong increase in winter and spring runoff at the beginning of the period, followed by a marked decrease in values in the middle of the period, and then a slight recovery. A continuous decrease in leakage is manifested during the summer and autumn, where after the strong increases from 1950-1970 there was a sharp decrease in the period 1980-1990, which did not recover until the 2000s, and a slight change in water regime, with a decrease in rainfall in autumn and an increase in winter.

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