PARTICULARITIES OF THE SEASONAL AND MONTHLY WATER FLOW REGIME TRENDS OF THE RIVERS FROM SUCEAVA HYDROGRAPHIC BASIN

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Abstract. Particularities of the seasonal and monthly water flow regime trends of the rivers from Suceava hydrographic basin. Suceava River is the first tributary of Siret River on Romanian territory and its basin includes parts of the eastern part of Eastern Carpathians (a part of Bukovina Ridges) and also a part of the Suceava Plateau. This placement results in some variation of river's water regime, both in space and time. For this study, we took into analyse the period 1960 – 2010 that presents high variations of river's seasonal water regime. The analysed data came from eight hydrometric stations inside Suceava river basin, three on the main course and five on the tributaries. We have analysed rivers discharges in all seasons, for the entire period of 50 years and for the decades included in this time period. The analysis used the MAKESENS Excel application to obtain the trend and slope of the data set. The results show changes from a season to another, and from a decade to another, with particularities presented for each period take into analysis.

Key-words: regime, hydrographic basin, Suceava, trend, water flow

1. INTRODUCTION

Suceava, the first tributary of the Siret on the right, has its origins in the northern part of Bucovina, south from Izvoarele Sucevei, at the altitude of 1250 m. Between Sipot and Ulma, on a distance of 21 km, it forms the border with Ukraine.

From the surface of 2.616 km^2 of its hydrographic basin, about 13% (340 km^2) is taking place on the territory of Ukraine, where it receives several more tributaries on the left (Sadău, Falcău, Laura, Sicova Bâlca Mare, Petrimasa, Târnavuca, Rusu and Ruda) .

On the territory of Romania, the hydrographic basin of Suceava River overlaps on three physic-geographical sectors with distinct features, from west to east. The western mountain range includes Obcina Feredeului and Obcina Mare. The transition area to the plateau region comprises a piedmont step and a series of depressions of different sizes. The eastern area belongs to the Suceava Plateau, a subunit attached to the Moldavian Plateau.

The hydrographic basin of the Suceava River is strongly asymmetric on the right, receiving the most important tributaries from the mountainous area (Pogonişoara, Nisipitu, Brodina, Ascunsul, V. Boului, Putna, Remezeu, Voitinel or Pietroasa, Pozen, Solca, Soloneț). In the plateau area there are smaller tributaries, both on the right (Ilişeşti, Şcheia) and on the left (Dragomirna, Plopeni and Salcea).

2. DATA BASE AND METHODS

The database used in the paper includes the average monthly and seasonal discharges calculated for eight hydrometric stations, three of which are located on the main course (Brodina 2, Țibeni and Iţcani) and five on the main tributaries (Figure 1).

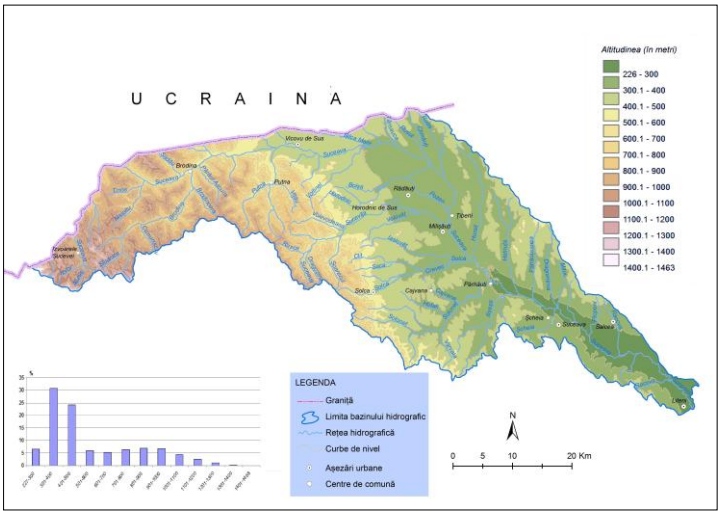

Fig. 1. Suceava River Basin

The period taken into account was 1960-2010, covering the possible non-periodic oscillations of the variables taken into account. The hydrological data related to the monthly average flows were taken from the Administration of the Siret River Basin in Bacau. The position, morphometric parameters of the basins controlled by hydrometric stations, as well as the annual and seasonal average water flow values are shown in Table 1.

Table 1. Data about the hydrometric stations used in the study

No. crt.	Hydr. station	River	Averg. Altit. (m)	Sur-face (km^2)	Q averg. (m^3/s)	% from average flow			
						W.	Sp.	Su.	A.
1.	Brodina 1	Brodina	989	142	1,715	8.5	34	41.3	16.2
2	Brodina 2	Suceava	990	366	4,3	8.5	35.4	39.7	16.4
3	Putna	Putna	847	53	0,631	10.2	33.2	40.8	15.7
4	Horodnic	Pozen	488	67	0,533	14.8	34.5	34.4	16.4
5	Țibeni	Suceava	730	1228	12,05	9.9	36.5	38.6	15
6	Părhăuți	Părhăuți	467	204	1,25	13.6	36.1	35	15.3
7.	Iţcani	Suceava	616	2377	16,99	10.6	36.3	37.9	15.2
8.	Șcheia	Șcheia	388	33	0,163	16.9	32.8	33.3	17

*W=Winter, Sp=Spring, Su=Summer, A=Autumn

In order to obtain the results required by the objectives of the paper, the data from A.B.A. Siret were organized and processed by various methods and procedures. Thus, statistical methods were used to obtain the average monthly and seasonal flows over the period, and the diagram methods were used to represent the quantitative data.

Monthly and seasonal trends were estimated using the MAKESENS Excel application (Mann-Kendall test for trend and Sen's slope estimates), created by the scientists at the Finnish Institute of Meteorology (Salmi et al., 2002). The non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1975) allowed the trend type (positive or negative) to be identified, and Sen's nonparametric method (Gilbert, 1987) allowed the estimation of the trend slope. Based on the slope values, the net modification was also calculated for the entire period taken into account and the net modification rate (%) determined as the percentage rate between the net modification and the average of the analysed data series.

Trends were calculated for the entire interval, thus identifying the general trend of monthly and seasonal flow in the studied area. In order to identify fluctuations, trends have also been calculated for each decade separately during the study period.

Also, for a more accurate analysis, we also attempted to achieve a qualitative appreciation of the values obtained. Thus, through a detailed analysis of the value ranges we have established several thresholds that correspond to five classes for increase and decrease trends (Table 2).

Table 2. Qualificatives and thresholds used for the monthly and seasonal flow of river water in the Suceav

Increase		Decrease	
Qualificative	**Threshold value**	**Qualificative**	**Threshold value**
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			

In Romania, the MAKESENS application has been used with satisfactory results in identifying the trend of climatic elements (rainfall, temperature) from different territories (Holobîcă, 2000, Mureşan and Croitoru, 2009, Croitoru and Toma, 2010, Mitof, 2016).

3. RESULTS AND DISCUTIONS

3.1. The trend of the seasonal flow during 1961-2010 in the Suceava River Basin

Following the calculated values for the whole period 1961-2010, it is observed that the trends of the seasonal flow are predominantly positive (increase), except for the spring season, when there are negative flow trends (decrease) at all the studied stations (Table 3).

Table 3. The values of the parameters of the seasonal spillage for the flows drained during 1961-2010 at the hydrometric stations in the Suceava river basin

Season	Hydro. station Parameters	Brodina 2	Putna	Horodnic	Țibeni	Pârhăuți	Ițcani
Winter	Trend (mm)	1,07	2,66	4,44	1,35	3,80	2,56
	Trend qualificative *	SI	MI	PI	SI	PI	MI
	Slope (mm/an)	0.00	0.00	0.01	0.03	0.01	43.32
	Modification (mm)	0.22	0.11	0.28	1.31	0.53	43.32
	Modification rate (%)	4.58	41.19	81.89	26.94	72.25	43.32
Spring	Trend (mm)	1.46	-0.43	-0.41	-1,37	-0.92	-0.97
	Trend qualificative*	SI	S	S	SD	SD	SD
	Slope (mm/an)	0.02	-0.002	-0.002	-0.001	-0.008	-0.128
	Modification (mm)	1.13	-0.08	-0.11	-0.07	-0.39	-6.38
	Modification rate (%)	23.96	-9.33	-14.23	-0.38	-20.49	-24.50
Summer	Trend (mm)	1,52	1,97	0,86	0,35	0,42	0,49
	Trend qualificative *	MI	MI	SI	S	S	S
	Slope (mm/an)	0.06	0.01	0.00	0.13	0.01	0.18
	Modification (mm)	2.90	0.65	0.24	6.55	0.61	9.11
	Modification rate (%)	58.09	59.55	30.25	33.43	33.17	33.57
Autumn	Trend (mm)	1,25	2,16	2,99	1,94	2,48	2,36
	Trend qualificative	SI	MI	MI	MI	MI	MI
	Slope (mm/an)	0.02	0.00	0.00	0.06	0.01	0.10
	Modification (mm)	1.25	0.23	0.24	2.76	0.42	5.00
	Modification rate (%)	24.58	55.80	63.69	37.10	51.78	46.65

* S – stationary, CU – slight increase, MI – moderate increase, PI – pronounced increase, SD – slight decrease

The values of the parameters corresponding to the increase trend of the seasonal flow differ in space and time. It can be observed a close correlation between the values of the trend parameters and the altitude of the areas controlled by the hydrometric stations under study.

Thus, with the exception of spring, increase trend values are higher with the altitude but at different gradients (Figure 2). The decrease trend in spring is also correlated with the altitude of the relief. The most pronounced spatial differences are observed in the summer, when two areas with different values of the gradients of increasing flow trend with altitude are emphasized.

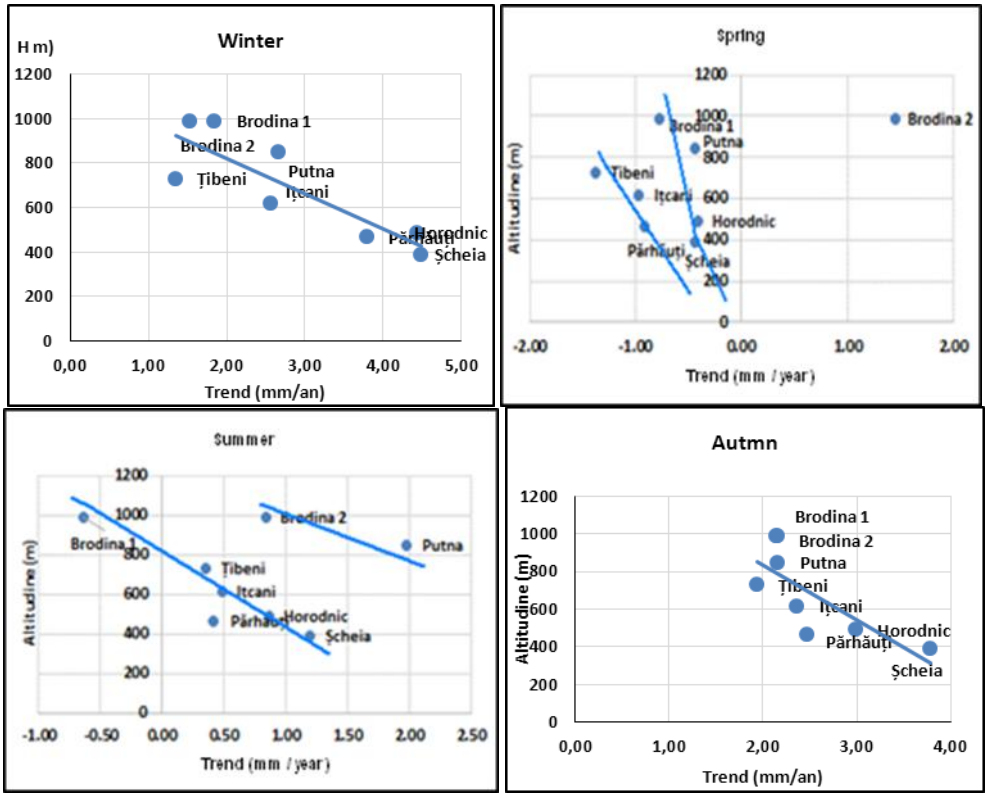

Fig. 2. The altitude variation of the values of the seasonal flow trend during 1961-2010 at the stations in the Suceava basin

The temporal differentiation of the intensity of the increase and decrease trends of the seasonal flow is conditioned by the physical particularities of the air masses displaced over the studied region within the zonal and local air circulation. Particularities of the atmospheric circulation necessitated significant temporal differences in the trend of the seasonal water flow.

In **winter**, the increase trend values are between 1.07 mm (Brodina 2) and 4.44 mm (Horodnic), being higher than those corresponding to the summer and autumn season. The increase trend varied from slight increase at Brodina 2 and

Țibeni stations, to pronounced at the stations Horodnic and Părhăuți. The high values of the increase trend are explained by the high frequency of hot air masses above the study area in this season towards the end of the analysis period, which caused the partial melting of the snow layer. The biggest changes in the flow trend were observed at Horodnic stations (81.8%), Părhăuți (72.2%) and Șcheia (63.6%). At stations from the main river, the net modification rate was much lower, below 50% (Țibeni - 26.9%, Ițcani 43%), which demonstrates the regulator role of the hydrographic area.

In **spring**, on most rivers, there was a decreasing trend in water flow due to the decrease of rainfall and the pronounced increase of air temperature in this season. The exception is the upper basin of Suceava River, where there was a slight increase of spring flow. In this area, characterized by high altitudes (over 900 m), precipitation diminution and air temperatures increase did not have such an strong effect on river water regime.The net modification rate varied between -24.5% (Ițcani) and -9.33% (Putna).

In **summer**, at the rivers with reception basins whose altitude are below 700 m, the run-off had a stationary character (Țibeni, Părhăuți, Ițcani). In contrast, on rivers that have reception basins with higher altitudes, the run-off trend was of slight (Horodnic) or moderate increase (Putna and Brodina).

Net modification rates were higher in the upper Suceava basin (58-60%) than in the middle and lower ones (30-34%).

In **autumn**, on all the rivers in the studied region there appeared a moderate increasing trend at most stations, and a slight increasing trend at Brodina 2.Net modification values remained between 24.6% (Brodina 2) and 63.7% (Horodnic).

3.2. The trend of the seasonal water flow regime over the decades from 1961-2010 in the Suceava River Basin

The sense of the seasonal flow tends to vary over the five decades included in the 1961-2010 period, each of which has its own features. They contribute with different proportions in defining the particularities of the seasonal flow trend in the study period. For the presentation of each decade's features, the processed data for the representative hydrometric stations on the collector river and the main tributaries were analysed.

Between 1961 and 1970, it was noted that at most hydrometric stations, the water flow remained stationary. The exception is Brodina 1 hydrometric station, where there was a slight decrease in water flow. In terms of net modification rate, the highest values correspond to summer (over 100%) and autumn (40-100%) seasons, and the lowest for spring and winter (Table 4).

Table 4. The values of the seasonal trends (in mm / year) and of the net modification rate (in %) during 1961-1970 at the hydrometric stations in the Suceava river basin

Station	Winter		Spring		Summer		Autumn	
	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)
Brodina	0.54	16.24	-0.18	-6.06	0.72	108.08	1.43	47.69
Brodina	0.89	12.09	0.36	29.22	2.33	170.86	1.07	15.40
Horodni	0.72	45.42	0.00	-0.69	1.07	84.67	2.68	116.03
Itcani	0.89	37.04	0.00	22.44	1.79	111.11	1.43	53.06
Parhaut	0.36	45.10	0.00	14.72	1.61	168.75	2.33	82.17
Putna	0.89	31.65	0.89	48.31	1.97	73.45	1.25	42.91
Scheia	1.79	64.83	0.00	89.15	1.43	173.35	2.50	48.83
Tibeni	0.89	37.06	0.00	22.43	1.79	111.10	1.43	53.07

In the following decade, **1971–1980**, the trend of seasonal flow had distinct features over the previous decade. Thus, spring and winter maintain the stationary character of the flow. The exception is Scheia hydrometric station, where the trend of winter flow was moderate increase (Table 5). The decreasing trend in autumn is noticeable at most hydrometric stations and corresponds to the negative values of the precipitation and temperature trends reported during this season.

Table 5. The values of the seasonal trends (in mm/year) and of the net modification rate (in %) from 1971 to 1980 at the hydrometric stations in the Suceava river basin

Station	Winter		Spring		Summer		Autumn	
	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)
Brodina 1	-0.18	-5.73	0.54	36.92	0.00	15.60	-0.54	-28.39
Brodina 2	-0.89	-5.78	0.18	15.81	0.54	27.33	-0.72	-24.48
Horodnic	0.18	9.50	1.25	116.02	0.00	-3.42	0.00	-0.12
Itcani	0.00	-0.56	0.89	73.10	0.00	-5.40	-0.36	-26.57
Parhauti	0.54	9.89	1.07	91.67	0.00	0.54	-0.89	-30.39
Putna	0.54	45.07	0.72	37.43	0.00	8.16	-0.18	-7.52
Scheia	2.15	44.56	1.89	177.39	0.89	61.13	1.17	24.39
Tibeni	0.00	-0.55	0.89	73.10	0.00	-5.41	-0.36	-27.28

In the 1981–1990 decade it was observed a large decrease in all seasons' trend (Table 6). The phenomenon is explained by the decreasing trend of precipitation quantities, which determined the most intense droughts in the analysed period. The trend of decreasing water flow was slight in winter and autumn and moderate in summer and spring (Table 6). The percentages of the net modification

rate were higher in spring (Șcheia - 179.4%) and autumn (Putna - 207.1%) on rivers with small basin areas that respond rapidly to sudden climate change.

Table 6. The values of the seasonal trends (in mm/year) and of the net modification rate (in %) from 1981-1990 to the hydrometric stations in the Suceava river basin

Station	Winter		Spring		Summer		Autumn	
	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)
Brodina 1	-0.54	-20.94	-1.61	-110.94	-1.43	-58.49	-0.36	-19.56
Brodina 2	-0.36	-5.12	-1.61	-96.51	-1.25	-56.86	-1.25	-8.60
Horodnic	-0.89	-44.37	-1.25	-136.83	-1.97	-118.74	-0.54	-19.05
Itcani	-0.89	-51.58	-1.43	-110.74	-1.43	-94.18	-1.07	-44.64
Parhauti	-1.61	-92.23	-1.97	-13.03	-1.61	-126.12	-1.07	-87.10
Putna	-1.79	4.09	-1.79	-43.41	-1.61	-44.01	-1.07	-207.11
Scheia	-0.36	-10.58	-1.61	-179.36	-1.25	-63.37	0.36	4.87
Tibeni	-0.36	-48.93	-1.25	-93.94	-1.07	-94.45	-0.89	-30.81

The 1991-2000 decade, except in the summer, was marked by an increasing trend of the seasonal flow. What is particularly noteworthy in this decade is that the generalized moderate and accentuated increasing trend in winter corresponds to the increase trend in rainfall. In spring and autumn there is a variation in the water flow trend from stationary to slight increase (Table 7). In summer, there appeared a decrease to stationary trend of the water flow (Brodina 2, Horodnic).This situation was due to the increasing trend of rainfall and temperatures in this decade, with climatic parameters tending to normalize after the decline in the previous decade.

Table 7. The values of the seasonal trends (in mm / year) and of the net modification rate (in %) during 1991-2001 at the hydrometric stations in the Suceava river basin

Station	Winter		Spring		Summer		Autumn	
	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)
Brodina 1	2.33	54.28	0.36	21.38	-1.07	-114.44	0.72	47.74
Brodina 2	1.61	18.43	0.89	60.59	0.00	-1.44	0.18	28.79
Horodnic	1.79	76.66	1.25	127.71	-0.18	-16.91	0.36	12.91
Itcani	2.68	82.55	0.72	50.48	-0.36	-48.69	0.54	40.09
Parhauti	2.33	117.08	0.54	81.74	-0.72	-62.32	0.89	45.18
Putna	2.33	121.80	0.89	49.55	-0.72	-40.95	2.15	134.98
Scheia	-0.18	-17.47	-0.18	-23.15	-0.36	-18.52	-0.36	-58.31
Tibeni	3.04	93.28	1.43	67.92	-0.18	-53.96	0.89	61.10

The 2001-2010 decade differs well from the previous one. Thus, during the winter there is a slight decrease in the upper Suceava River Basin and Pozen River. In contrast, on the middle and lower course of Suceava River and the tributaries with low basin altitudes (Şcheia), the water flow trend was of slight and moderate increase. In spring and summer, water flow trend ranged from stationary (Horodnic, Brodina 2) to slight and moderate increase (Table 8). In autumn, at most hydrometric stations, the water flow trend was stationary or slight decrease (Brodina 1).

Table 8. The values of the seasonal trends (in mm / year) and of the net modification rate (in %) during 2001-2010 at the hydrometric stations in the Suceava river basin

Station	Winter		Spring		Summer		Autumn	
	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)	Trend (mm/an)	Modif. rate (%)
Brodina 1	-1.07	-40.99	0.89	28.21	1.61	65.23	-0.72	-34.64
Brodina 2	0.18	5.54	0.18	1.67	0.36	62.57	0.00	-4.88
Horodnic	-1.35	-39.13	0.45	21.25	0.63	138.89	-0.27	-10.31
Itcani	0.72	21.57	0.72	35.09	0.89	62.54	-0.36	-25.22
Parhauti	1.25	28.54	1.07	70.71	0.72	96.40	0.00	-11.28
Putna	-0.54	-20.83	0.00	-15.73	0.36	32.87	-0.54	-64.30
Scheia	1.61	47.43	1.79	67.75	1.97	214.29	0.36	7.50
Tibeni	0.72	37.74	0.89	32.07	0.89	117.63	-0.89	-34.22

CONCLUSIONS

The seasonal water flow regime from the period 1961-2010 showed significant variations, determined by the particularities of the atmospheric circulation, and influenced by the local features of the relief (altitude, slope, orientation of the basins and slopes, etc.) and hydrographic basins.

The increase in Mediterranean cyclone activity over the studied area caused a trend increase in autumn and winter during 1961-2010, manifested by an increase in winter temperatures towards the end of the period and an increase in rainfall during autumn.

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