PARTICULARITIES OF AIR TEMPERATURE'S SEASONAL TRENDS IN SUCEAVA HYDROGRAPHIC BASIN

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Abstract. Particularities of air temperature's seasonal trends in Suceava hydrographic basin. The Suceava River, the first large tributary to Siret River on the Romanian territory, gathers its tributaries from two major relief groups: the mountain and the plateau, with a boundary sector between the two. This influences the distribution in altitude of the climatic values in the basin, especially the temperature.
For this work, the period 1960 - 2010 was analysed, a long enough period to be considered representative for temperature variation in this basin. The temperature data were obtained from the ROCADA program for the entire analysed basin, with five representative stations. Temperatures have been analysed for the entire 50-year period and for the decades included. For this purpose, was used the MAKESENS Excel application to obtain the trend and slope of the dataset. The results show interesting values, varying from one season to another, and from one decade to the next, with major implications in the river water regime in the Suceava hydrographic basin.

Key-words: temperature, hydrographic basin, Suceava, trend.

1. INTRODUCTION

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

From its 2.616 km^2, about 13% (340 km^2) belong to the Ukrainian territory, from where it receives several smaller tributaries (Sadău, Falcău, Laura, Sicova Bâlca Mare, Petrimasa, Târnavuca, Rusu and Ruda).

On Romanian territory, the hydrographical basin of the Suceava River overlaps three sectors with distinct physical-geographical features, from west to east. The western mountain range includes Obcina Feredeului and Obcina Mare. The transition sector to the plateau region comprises a piedmont area and a succession of different size depressions. The eastern area belongs to Suceava Plateau, a subunit attached to the Moldavian Plateau.

The Suceava hydrographic basin is strongly asymmetric on the right, receiving the most important tributaries from the mountainous area (Pogonisoara, Nisipitu, Brodina, Ascubsul, Boului Valley, Putna, Remezeul, Voitinelul, Pietroasa, Pozenul, Solca, Soloneț, etc.). From the plateau area, it receives smaller tributaries, both on the right (Ilişeşti, Şcheia) and on the left side (Dragomirna, Plopeni and Salcea).

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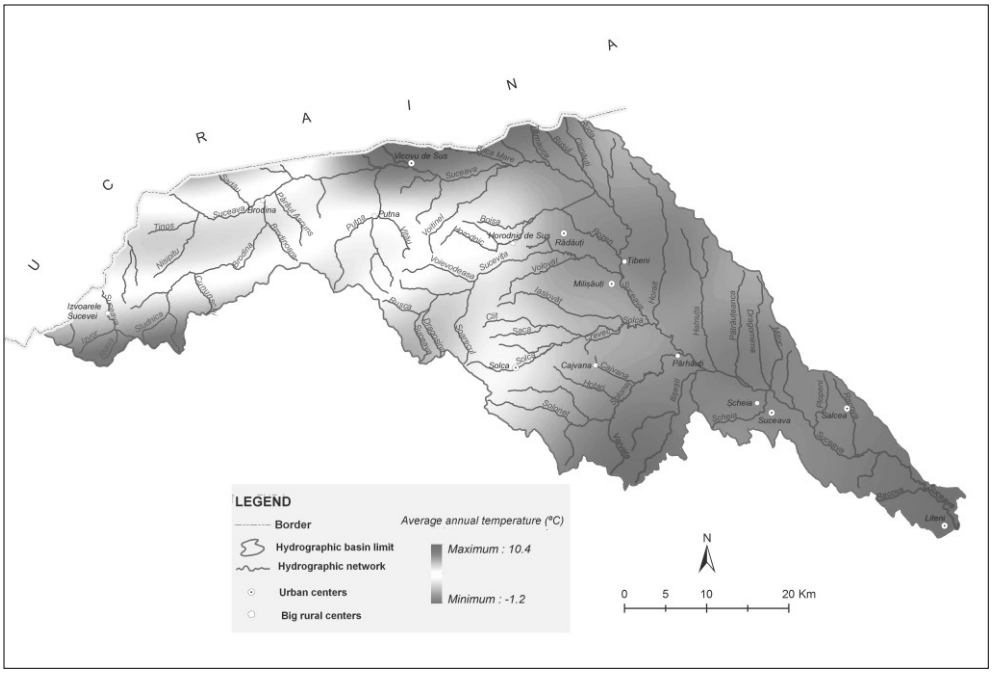

Fig. 1. Variation of annual average temperatures in Suceava hydrographic basin during 1960-2010

2. DATA BASE AND METHODS

The database used in this paper includes the annual temperature values processed from daily climatic data for 5 measuring points (stations, according to Birsan, M.-V., Dumitrescu, A. (2014)) obtained using the ROCADA program (Fig. 1). The position, characteristics of climatic stations, as well as the annual and seasonal average temperature values are given in Table 1. The period taken into account was 1960-2010, covering the non-periodical oscillations of the variables taken into account.

Tabel 1. Annual and seasonal average temperature values at the meteorological stations from Suceava hydrographic basin (data processed after Birsan, M.-V., Dumitrescu, A. (2014))

No. Crt.	Meteorological Station	Altit. (m)	Latit.	Longit.	Annual average temperatures	Seasonal average temperatures '			
						W.	Sp.	S.	A
1	Brodina	1016	47º90' N	25º40' E	4,09	-5.66	3.77	12.86	5.19
2	Izvoarele Sucevei	910	47º80' N	25º20' E	3,63	-5.72	3.12	12.32	4.62

No. Crt.	Meteorological Station	Altit. (m)	Latit.	Longit.	Annual average temperatures	Seasonal average temperatures '			
						W.	Sp.	S.	A
3	Margine a	446	47º80' N	25º80' E	6,22	-4.28	6.16	15.93	6.89
4	Pârhăuți	300	47º70' N	26º10' E	8,01	-2.82	8.15	17.93	8.61
5	Suceava	432	47º70' N	26º30' E	8,44	-2.33	8.84	18.63	9.18

W=Winter, Sp=Spring, S=Summer, A=Autumn

In order to obtain the results required by the objectives of this paper, the data obtained from ROCADA were organized and processed by different methods and procedures. Thus, statistical methods were used to obtain the average seasonal temperatures for the analysed period, and the diagrams were used to represent the quantitative data.

Seasonal trends were estimated using the Mann-Kendall test for trend and Sen's slope estimates created by researchers from the Finnish Meteorological Institute (Salmi et al., 2002). The non-parametric Mann-Kendall allowed the trend type to be identified (positive or negative) and Sen's nonparametric method allows estimation of the trend slope. Based on the slope values, net modification was also calculated over the entire period taken into account and the net modification rate (%) determined as the percentage modification 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 seasonal temperatures in the studied area. To identify fluctuations in temperature values, trends were also calculated for each decade separately within the study period.

Also, for a more accurate analysis, a qualitative assessment of the values obtained was attempted. Thus, through a detailed data analysis, there was established several thresholds that correspond to five classes for increasing and decreasing trends (Table 2).

Table 2. Qualificatives and thresholds used for the seasonal air temperature in the Suceava hydrographic basin

Increase		Decrease	
Qualificative	Threshold	Qualificative	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			

In Romania, the MAKESENS application has been used with satisfactory results in identifying the tendency of climatic elements (precipitation, temperature) from different territories (Holobîcă, 2006, Croitoru and Toma, 2010, Mitof, 2016).

3. RESULTS AND DISCUTIONS

3.1. Trend of seasonal temperatures in 1961-2010

Following the values obtained for the period 1961-2010, a positive temperature trend in the entire Suceava hydrographic basin was observed, a trend which varied from stationary in winter to all stations, to pronounced increase during spring and autumn at all stations (Table 3).

Table 3 The trend (in ^{0}C/year) of seasonal temperatures and the modification rate (in %) for air temperatures in the period 1961-2010 at the station taken into study

Season	Hydro. Station/ Parameters	Brodina	Izvoarele Sucevei	Marginea	Părhăuți	Suceava
Winter	Trend qualificative *	MI	MI	MI	MI	MI
	Slope (mm/an)	0.04	0.03	0.04	0.05	0.05
	Modification (mm)	1.83	1.59	2.03	2.39	2.37
	Modification rate (%)	37.70	27.83	47.39	85.06	96.22
Spring	Trend qualificative *	MI	MI	MI	MI	MI
	Slope (mm/an)	0.02	0.02	0.03	0.03	0.03
	Modification (mm)	1.17	1.18	1.36	1.74	1.71
	Modification rate (%)	22.88	37.67	22.12	21.31	20.04
Summer	Trend qualificative *	PI	PI	PI	PI	PI
	Slope (mm/an)	0.04	0.04	0.04	0.04	0.04
	Modification (mm)	2.12	2.61	2.57	2.54	2.56
	Modification rate (%)	14.61	21.20	16.17	14.14	13.91
Autumn	Trend qualificative *	S	S	S	S	S
	Slope (mm/an)	0.00	-0.01	0.00	0.00	0.00
	Modification (mm)	0.01	-0.26	0.06	0.08	0.02
	Modification rate (%)	0.10	-5.62	0.87	0.89	0.20

Although the values of the temperature trend do not vary from one station to another during a season, these being homogeneous in the entire basin, differentiations are made at the modification (%), some stations presenting much higher values, as a result of the Sen's slope values (Table 3) during winter – Părhăuți (85.06%) and Suceava (96.22%).

In relation to the altitude, the variation of temperature trend is very well highlighted, maintaining the rule of increase/decrease of temperature in altitude, best highlighted during winter and summer. The only exception is during autumn, when negative trend values (Fig. 2) are recorded at the Izvoarele Sucevei Station due to the station's placement in the western basin part, where the strong orographic influences cause the temperatures to remain at lower values.

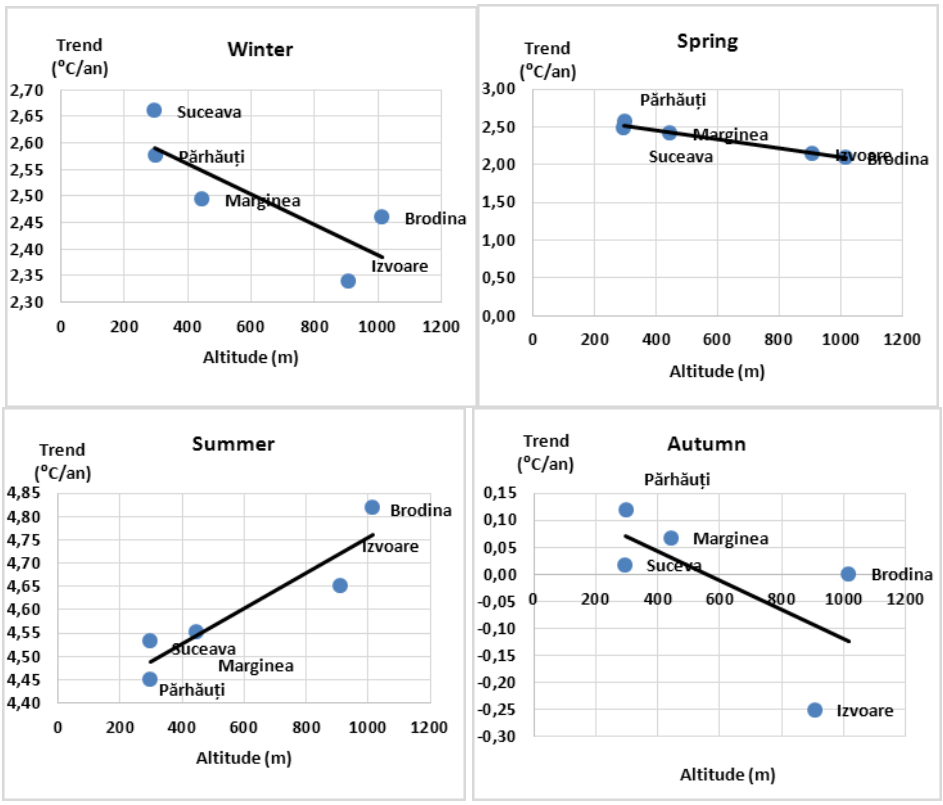

Fig. 2. The variation in altitude of seasonal temperature trend values during 1961-2010.

Differences over time in temperature variation are determined by the atmospheric air circulation above the basin in the study, with local peculiarities influenced by the relief factor (***(1984), *** (1987)). These differences have subsequently strongly influenced the other climatic parameters and the river drainage, with long-lasting effects.

In winter, the temperature trend presented a moderate increase, with values ranging from 2.34°C/year (Izvoarele Sucevei) to 2.66°C/year (Suceava). These were corroborated with slope values ranging from 27.83% (Izvoarele Sucevei) and 96.22% (Suceava), observing very clearly the temperatures increase which affected much the plateau sector compared to the mountain one, where the altitude has mitigated some of the increase. The effect of temperature increases has been felt in the river runoff, which, as a result of increasing temperatures, has also increased to similar levels, sometimes even higher (Porcuțan, Adriana, Sorocvschi, V. 2017).

In the spring, the temperature trend values registered a moderate increase, ranging between 2.09°C/year (Brodina) and 2.56°C/year (Părhăuți). The values increased inversely proportional with the the altitude, the highest being recorded in the plateau sector. The slope values were positive, ranging between 20.04% (Suceava) and 37.67% (Izvoarele Sucevei). The increase of spring temperatures was due to global warming during 1961-2010, which affected the mountain sector in particular.

Summer is the season where the highest temperature increases have been recorded, with an increasing trend in the entire basin. These values varied between 4.45°C/year (Suceava) and 4.82°C/year (Brodina), showing a trend increase proportional with the altitude. Increases also recorded for the rate values, but lower than for the trend, ranging from 13.91% (Suceava) and 21.20% (Izvoarele Sucevei). Although the general increase has been pronounced in this season, it seems that some colder times have mitigated the maxima of other periods.

During the autumn, trend values varied the least, from -0.25^{0}C/year at the Izvoarele Sucevei station and 0.12^{0}C/year at the Părhăuți station. The negative trend of temperature values in the mountain sector (Izvoarele Sucevei station) is insignificant and cannot be based on obvious climatic influences. This is also evidenced by the Sen's slope values, which remained between 0-1%, with only the respective station registering -5.62%.

3.2. The trend of seasonal temperatures during the decades from the period 1961-2010

a. The decade 1961-1970 was characterized by a stationary temperature trend in winter (0.18-0.72^{0}C/year) and spring (0-0.18^{0}C/year) with positive values. The stationary trend was maintained in the other two seasons, but with negative values, presenting slight decreases in the mountain sector in the autumn (Table 4). With regard to the net modification rate, the Izvoarele Sucevei station differentiate from the other stations, with the highest recorded values, respectively the lowest ones, in winter (89.87%) and autumn (-88.51%).

Table 4. The trend (in ^{0}C/year) of seasonal temperatures and of modification rate values (in %) for the air temperature registered in the period 1961-1970

Meteo. station	Winter		Spring		Summer		Autumn	
	Trend (^{0}C/year)	Modif. rate (%)	Trend (^{0}C/year)	Modif. rate (%)	Trend (^{0}C/year)	Modif. rate (%)	Trend (^{0}C/year)	Modif. rate (%)
Brodina	0.54	18.01	0.00	3.21	-0.72	-3.07	-1.43	-8.60
Izvoarele Sucevei	0.18	89.87	0.18	3.37	-0.89	-36.07	-1.07	-88.51
Marginea	0.72	20.34	0.00	1.63	-0.72	-14.07	-0.72	-47.89
Părhăuți	0.72	22.98	0.00	1.25	-0.36	-12.46	-0.54	-44.77
Suceava	0.89	25.43	0.00	-1.35	-0.36	-10.66	-0.72	-49.57

b. The decade 1971-1980

In this decade, the general trend of temperatures was stationary to slight decrease (Table 5), trend which was also appeared in the rivers flow. Only in autumn were recorded positive values, and even slight increase at mountain stations. The extreme values of the net modification rate were also recorded at Izvoarele Sucevei, where the values varied between -52.20% (in summer) and 206.65% (in autumn), showing a strong general warming trend during this decade.

These values have been corroborated with declining trends in precipitation, which show a generally cooler period.

Table 5. The trend (in ^{0}C/year) of seasonal temperatures and the modification rate (in %) for air temperatures during 1971-1980

Stație	Iarna		Primavara		Vara		Toamna	
	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)
Brodina	-1.07	-31.70	-0.89	-29.82	-1.07	-5.76	1.07	25.71
Izvoarele Sucevei	-1.61	-31.95	-0.89	-51.14	-1.25	-52.20	1.25	206.65
Marginea	-1.07	-56.54	-0.72	-17.08	-1.25	-24.62	0.72	48.39
Pârhăuți	-0.89	-72.98	-0.72	-6.25	-1.25	-22.91	0.72	41.82
Suceava	-0.89	-92.71	-0.54	-5.95	-1.07	-17.72	0.18	34.51

c. The decade 1981-1990

During this decade appeared a stationary positive trend of temperature values (Table 6) for all seasons, with the exception of autumn, when the trend was stationary, but the values were negative.

Table 6. The trend (in ^{0}C/year) of seasonal temperatures and the modification rate (in %) for air temperatures during 1981-1990

Stație	Iarna		Primavara		Vara		Toamna	
	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)
Brodina	1.25	0.63	0.54	0.06	0.54	0.16	-0.72	-24.09
Izvoarele Sucevei	1.43	0.79	0.18	4.79	0.72	29.83	-0.72	-274.95
Marginea	1.07	1.36	0.72	0.22	0.54	1.85	-0.72	-84.24
Pârhăuți	0.89	24.40	0.72	3.70	0.72	63.62	-0.72	-29.52
Suceava	0.89	4.64	0.54	0.14	0.72	4.16	-0.89	-43.59

For the net modification rate, the Pârhăuți station distinguishes itself, with the highest recorded values in winter (24.4%) and summer (63.62%), and Izvoarele Sucevei Station, where appeared the smallest values during autumn (-274.95%). This shows that the increase of temperature values was stronger in the plateau sector, where, combined with the lack of precipitation during this period, a severe drought has occurred. In autumn, strong negative trend values show a generalized decrease in temperatures, which was also manifested by a decreasing trend of river water flows.

d. The decade 1991-2000

This decade showed a general stationary trend (Table 7), the only stations with slight increases in winter and spring were those in the plateau sector. There have also been periods of drought in this decade, also evidenced by lower water flow values.

Table 7. The trend (in ^{0}C/year) of seasonal temperatures and the modification rate (in %) for air temperatures during 1991-2000

Stație	Iarna		Primavara		Vara		Toamna	
	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)
Brodina	0.36	10.62	-0.18	-39.66	0.54	2.28	0.36	12.18
Izvoarele Sucevei	0.36	11.86	0.00	-8.90	0.54	26.78	0.18	45.04
Marginea	1.25	40.05	0.54	6.21	0.36	22.41	0.36	74.61
Pârhăuți	1.43	97.96	1.25	19.02	0.54	21.82	0.18	43.25
Suceava	1.43	107.18	1.25	18.31	0.54	23.89	0.18	35.63

The net modification rate was also positive, with the values for the plateau sector station being the highest.

e. The decade 2001-2010

This decade, compared to the previous ones, maintains the positive stationary trend in the winter, but it becomes negative stationary in spring and even slightly increasing in summer and autumn (Table 8) when the highest values are reached (1,43^{0}C/year).

Negative values during spring, along with the increasing rainfall trend, triggered the very rainy springs of this decade, which, along with summer storms, generated by warm weather, followed by strong rains, helped create catastrophic floods in Suceava hydrographic during 2005-2010.

The modification rates were also highest during autumn, reaching a 173.9% increase at Izvoarele Sucevei.

Table 8. The trend (in ^{0}C/year) of seasonal temperatures and the modification rate (in %) for air temperatures during 2001-2010

Stație	Iarna		Primavara		Vara		Toamna	
	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)	Tendinta (^{0}C/an)	Rată modif. Netă (%)
Brodina	0.89	25.58	-0.18	-9.26	1.25	5.54	1.43	13.41
Izvoarele Sucevei	0.89	20.24	-0.54	-16.44	1.07	33.33	1.43	173.90
Marginea	0.36	21.31	-0.18	-4.98	1.07	36.68	1.43	70.70
Pârhăuți	0.18	33.68	-0.18	-1.83	0.72	34.49	0.89	54.99
Suceava	0.18	38.80	-0.18	-1.11	0.89	30.70	1.43	57.73

4. CONCLUSIONS

Temperatures play an important role in forming a river water regime for a hydrographic basin (Sorocovschi, V., 2010). They are correlated with the precipitation and influence the amount of water comes in (through rainfalls, snow) and out (through evaporation) of a river.

The study period, although exhibiting a general moderate-to-pronounced increasing trend for almost all seasons (excluding autumn), showed strong variations from one decade to the next, with the decade 1970-1980 highlighting a general decreasing trend in the entire basin. In the other decades, the trend has varied in each season, with values ranging from slight decreases to slight increases, which, in conjunction with each other, have given major variations at some climatic stations throughout the entire period.

The variation of the temperature slope values was also in line with the trend variation, the extreme values being recorded during autumn at Izvoarele Sucevei in the mountain sector.

From this analysis it results that the temperatures influenced the water flow in the Suceava hydrographic basin, especially in those periods when the precipitations did not strongly influence the regime (winter, autumn), in the rest of the seasons being accompanied by the variation of precipitation values.

REFERENCES

1. Birsan, M.-V., Dumitrescu, A. (2014) - ROCADA: Romanian daily gridded climatic dataset (1961-2013)V1.0., Administratia Nationala de Meteorologie, Bucuresti, Romania, doi:10.1594/PANGAEA.833627

2. Croitoru, Adina-Eliza (2006), *Excesul de precipitații din Depresiunea Transilvaniei*, „Casa Cărții de Știință" Publishing House, Cluj-Napoca, Romania
3. Holobîcă, I.H. (2006) – *Perioadele deficitare sub aspect pluviometric şi efectele lor hidrologice în Podişul Transilvaniei*, Teză de doctorat, UBB, Cluj-Napoca
4. Mitof, I. (2017) - *Resursele de apă din nord-estul Câmpiei Române (între râurile Călmățui și Buzău),* teză de doctorat, Universitatea Al. I. Cuza, Iași
5. Porcuțan, Adriana, Sorocovschi, V. (2017) - *Particularities of the seasonal water flow regime trends of the rivers from Suceava hydrographic basin*, în "Riscuri şi catastrofe", NR. 1/2017, editor Victor Sorocovschi, Editura "Casa Cărții de Știință", Cluj-Napoca
6. Salmi, T., Määttä, A., Anttila, Pia, Ruoho-Airola, T., Amnell, T. (2002) - *Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates - the Excel template application Makesens*, Publicație în "Air quality No. 31", Report code FMI-AQ-31, Finnish Meteorological Institute, Helsinki, Finland
7. Sorocovschi, V. (2010), *Hidrologia uscatului*, Edit. Casa Cărții de Știință" Cluj-Napoca
8. *** (1983), *Geografia României. Vol. III*, Editura Academiei Republicii Socialiste România, Bucureşti , România
9. *** (1987), *Geografia României. Vol. IV*, Editura Academiei Republicii Socialiste România, Bucureşti , România