TREND ANALYSIS OF TEMPERATURE, PRECIPITATION AND RIVER DISCHARGE IN THE RASINA RIVER BASIN, SERBIA

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ABSTRACT

In this research, changes in air temperature, precipitation and discharge were analyzed on the territory of the Rasina River basin (central Serbia). Monthly and annual temperature and discharge means, as well as monthly and annual sums of precipitation for all the stations in the period of 60 years (1961–2020), were provided by the Republic Hydrometeorological Service of Serbia. The change detection analysis has been conceded using Pettitt's test, while the linear regression, Mann-Kendall, and Sen's slope tests have been applied for trend analysis. The analysis indicated that the average annual, winter, spring and summer temperatures show a significant increasing trend both in the longer period (1961–2020) and in the second part of the period (1991–2020). In the first part of the period (1961–1990), annual and autumn temperatures in Kruševac, showed a significant decreasing trend. The seasonal precipitation increased for all seasons, as well as temperatures, except for spring in the first period (1961–1990) and autumn in the second period (1991–2020) in both stations. Obtained results of mean annual and mean seasonal discharge trends are generally not statistically significant. The exceptions are winter discharges in Bivolje in the period 1961–2020 and mean discharges in Brus (1961–1990), where a moderate significance decrease is recorded. The discharge is lower in the second half-period for all seasons. The Pettitt test determined that there was a change point detection in the data. For the year 1981, it was established that there was a significant decrease in annual discharge on the Rasina River in Brus, from 2.82 m^3/s to 2.21 m^3/s; in 1983 there was a significant increase in annual temperature in Kopaonik, from 2.62°C to 4.69°C. 1998 also showed an increase in temperature in Kruševac, from 10.86°C to 12.4 °C.

Keywords: temperature, precipitation, discharge, statistical homogeneity test, Mann-Kendall test, Rasina River

INTRODUCTION

Trend changes in climate are the most important topic in climatic research of the last few decades and are still one of the main challenges nowadays (Arora et al., 2005). Climate change and human activities are two major drivers of hydrological regime modifications (Gnjato et al., 2019). Recent climate change has already affected the global hydrological cycle. These effects have manifested in changing the seasonal river flows and increasing the frequency of occurrence of floods and droughts (but also in their severity) in some regions. The major factor of climate change is the increasing temperature. According to the IPCC (2013) report, the average global surface temperature of the world has increased by 0.74 °C± 0.18 °C in the past 100 years. Available records show that the 1990s have been the warmest decade of the millennium in the Northern Hemisphere. The annual mean surface air temperature has increased significantly in

almost all parts of Serbia (Stričević et al., 2022). The rises in temperatures were higher in the northern than in the southern parts of Serbia, and the increase was the highest in spring (Malinović-Milićević et al., 2015). The regions with the greatest increase in temperature are Eastern Serbia and the region of Vojvodina (Radivojević et al., 2015; Gavrilov et al., 2015, 2016). Another important factor is the variability of precipitation. The precipitation in an area is an important factor in determining the amount of water available to meet various demands, such as agricultural, industrial, and domestic water supply, as well as the water used for hydroelectric power generation (Panda et al., 2019).

Milanović et al., (2015) found an increasing trend for the mean annual precipitation in most of the areas in Serbia. The results of Malinović-Milićević et al., (2015) showed that the amount and intensity of precipitation showed a statistically significant increase only during autumn, and this was most pronounced in the northern and western parts of the country. Over the past several decades, numerous studies all over the world have analyzed river discharge variability and its relations to recent climate change (Cherinet et al., 2019; Da Silva et al., 2015; Croitoru et al., 2015; Gnjato et al., 2019; Hu et al., 2019; Zaghloul et al., 2022). In Europe, river discharges decreased over the southern and eastern parts of the continent, whereas a positive trend was noticed for some rivers discharging into the North Sea and Eastern Atlantic (Gnjato et al., 2019). A significant negative trend in annual and seasonal discharges was detected in Serbia (in all seasons except autumn) (Kovačević-Majkić et al., 2014; Langović et al., 2017; Langović, 2019; Martić Bursać et al., 2022).

In the present study, statistical methods of trend detection and change point analysis have been used for annual and seasonal temperature, discharges and sum of the precipitations in the Rasina river basin, from 1961 to 2020. The objective of the research was to examine the homogeneity of the data during the period of observation, and to pinpoint the components of a trend in the analyzed data on annual and seasonal average data. The research results will not only provide evidence for climate change in the Rasina river basin but can also lay the foundation for further studies on water resources security evaluation in conditions of climate change.

MATERIALS AND METHODS

Study Area

The basin of the Rasina River is situated in the south part of the Central Serbia with a surface area of 979,6 km^2 (Stričević, 2015). The Rasina River emerges on the east and south-east slopes of the mountains of Goč, Željin and Crni vrh where its constituents the Velika river and the Burmanska river emerge (Filipović et al., 2017). If the Burmanska river is taken as the main source of the Rasina River, then its total length is 92.3 km. The Rasina is the biggest right tributary of the Zapadna Morava, which empties at the town of Kruševac at 134 m above sea level. The basin of the Rasina River is asymmetrical-the surface area of the left side of the watershed is 191.4 km^2 (19.5%), and right-788.2 km^2 (80.5%). The Rasina River has 96 tributaries – 37 left (10 constant and 27 periodical tributaries) and 59 right (35 constant and 24 periodical tributaries). Significant tributaries are:the Graševačka river (21.3 km), the Blatašnica river (14.5 km) and the Lomnička river (17 km) on the right, and Zagrža river (11,3 km) on the left (Stričević, 2015).

The climate of the Rasina River basin is highly determined by its geographical position and relief. The largest part of the Rasina river basin is situated in the zone of temperate continental climate with continental pluviometric regime, while mountainous climate is represented on the mountain edge of the basin. According to Kepen's classification, most of the basin belongs to the so-called C climate, i.e. moderately warm, with the exception of the mountainous area of Kopaonik, which belongs to the D climate - moderately cold climate (Stričević et al., 2022).

Maximum average monthly discharges in the Rasina River basin were recorded in April and March, as a result of the melting snow from the surrounding mountains and intensive spring precipitations, while minimum average discharges occurred at the end of summer and the beginning of autumn, as a consequence of lower precipitation amount in the warmer part of the year, as well as high summer air temperatures and evaporation.

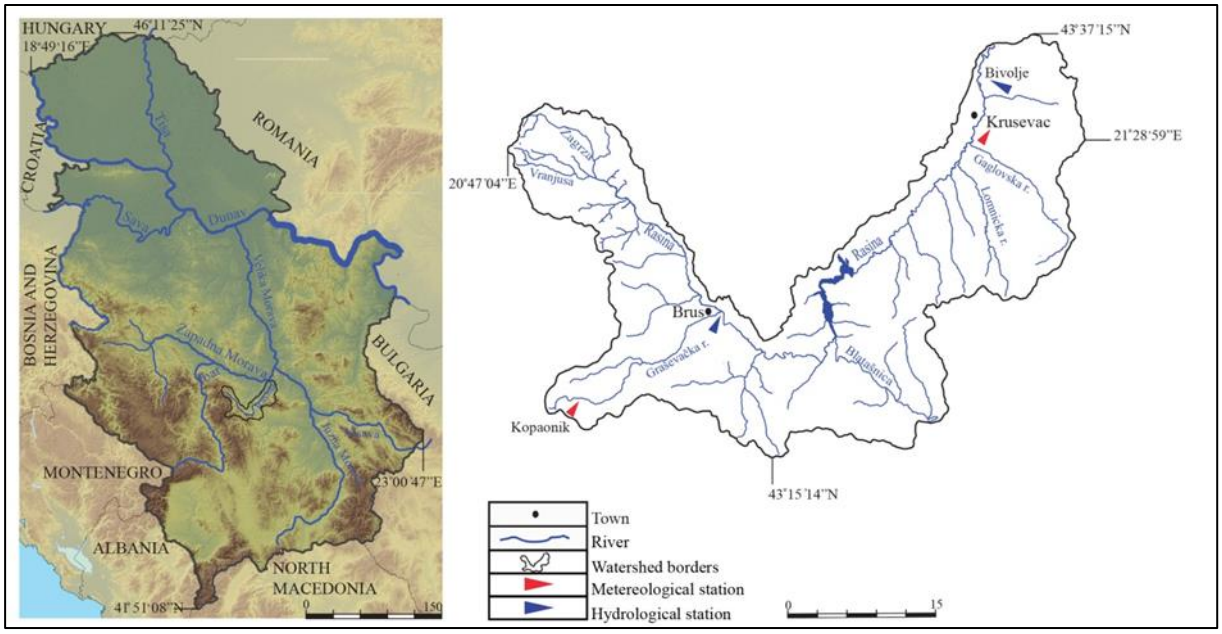

Figure 1. Geographical location of the research area and position of meteorological and hydrological stations in the Rasina River basin.

Data

Seasonal and annual climate data were examined, temperatures and precipitation in the towns of Brus and Kruševac, as well as discharge data from the two gauges on the Rasina river, Brus and Bivolje. Monthly and annual temperature and discharge means, as well as monthly and annual sums of precipitation for all the stations in the period of 60 years (1961–2020), were provided by the Republic Hydrometeorological Service of Serbia (RHMS). The locations of the stations are presented in Figure 1. Seasons were defined as follows: winter-W (December–February), spring-Sp (March–May), summer-Sm (June–August) and autumn-A (September–November). All the seasons correspond to the calendar year except for the winter season, which corresponds to January – February of the calendar year and to December of the previous year. As the time series was 60 years long, it was long enough to divide it into two equal 30-year-long periods, to find out if the series is homogenous, if it is a trend, and what the possible cause of

the changes is. The first half of the period occurred between 1961–1990, while the second occurred between 1991 and 2020.

Methodology

To determine the existence of a trend in annual and seasonal analyzed data, this paper used the non-parametric statistical method – Mann–Kendall test and Pettit's homogeneity test.

Pettit's test is a non-parametric test, which is useful for evaluating the occurrence of abrupt changes in climatic records. According to Pettit's test, if there is a change point in a series of n observed data, the distribution function of the first t samples F1 will be different from the distribution function of the second part of the series F2. The null hypothesis H0 implies that the data are homogeneous throughout the period of observation, and alternative hypothesis H1 implies the presence of a non–accidental component among data causes a shift of the location parameter at a particular moment. Aside from providing for a data homogeneity check, Pettit's test also determines if the alternative hypothesis happens to accept the change-point when a shift of the location parameter occurs (Pettit, 1979).

The statistical significance of the trend in annual and seasonal series was analysed using the non-parametric Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of an increasing or decreasing trend (Kumar et. al., 2010). The positive values of Z (level of significance) indicate upward (increasing) trends in the time series, and the negative values show downward (decreasing) trends. Sen's slope estimator was used to compute the climate indices percentage of change over each year for the 60-year period (1961–2020). The value would indicate for instance how much on average it has modified each year either positively or negatively (indicating direction and size of trend) by overcoming the gross data time series errors and outliers if any (Doshi et al., 2023).

RESULTS AND DISUCCSION

In the present study, Pettitt's test has been applied to detect a change point in annual and seasonal series of temperature, precipitations and discharges in the Rasina river basin. For the used test, we failed to reject the null hypothesis when the estimated p-value was greater than the significance level of 0.05. After detecting the change point, the trend analysis was applied by using linear regression and the Mann-Kendall test. Trends are tested against some critical values to show whether they are statistically significant or not. In this study to represent the confidence level ***, **, * and + signs have been used to represent 100%, 99%, 95% and 90% levels of confidence respectively. The test statistics acceptance or rejection of the null hypothesis for annual and seasonal DATA has been presented in Table 1–6. Figs. 2–7 show annual and seasonal mean temperatures, precipitations and discharges, during the period 1961–2020 with three trend equations: above (1961–2020) and below (1961–1990 and 1991– 2020); and three trend lines: for longer and two shorter periods, respectively.

Temperature

The average annual and seasonal series in the period 1961-2020 on both stations indicated a significant change point, except on Kopaonik, where autumn data can be considered homogeneous. The test results indicate that the change in average annual temperature occurred in 1998 in Kruševac and 1983 on Kopaonik. The average annual temperature in the second period increased in Kruševac from 10.86ºC to 12.14 ºC and on Kopaonik it increased from 2.62ºC to 4.69 ºC. The average annual temperature for the period 1961–2020 is 11.4 °C in Kruševac and 3.9 °C on Kopaonik (Table 1).

Pettitt's test indicates the increase in average winter temperatures in Kruševac from 1991, while on Kopaonik the increase started in 1986. The analysis of spring temperature confirmed that the change point may have occurred in 1997 in Kruševac, while it may have occurred on Kopaonik in 1980. The change in average summer temperature occurred in 1990 in Kruševac and 1986 on Kopaonik. The average summer temperature in Kruševac increased from 20.06ºC to 21.82 ºC, and on Kopaonik it increased from 10.31ºC to 12.56 ºC.

Table 1. Pettitt's test statistic – Kruševac and Kopaonik-temperature (°C)

Period	Variable	Kruševac					Kopaonik				
		T_{av}	W	S_p	S_m	A	T_{av}	W	S_p	S_m	A
1961–2020	Mean (°C)	11.359	1.22	11.675	20.925	11.612	3.883	-4.653	1.992	11.624	4.729
	Kt	751	424	518	771	407	778	604	649	810	333
	tc	1998	1991	1997	1990	1997	1983	1986	1980	1986	2006
	p	0.0001	0.006	0.0002	0.0001	0.008	0.0001	0.0001	0.0001	0.0001	0.053
	T1	10.861	0.684	11.205	20.05	11.218	2.622	-5.58	0.505	10.292	4.729
	T2	12.139	1.856	12.464	21.831	12.324	4.689	-3.971	2.595	12.603	4.729
1961–1990	Mean (°C)	10.814	0.776	11.269	20.048	11.169	2.931	-5.314	1.107	10.497	4.321
	Kt	53	108	40	91	144	204	115	133	156	68
	tc	1967	1968	1964	1971	1968	1976	1976	1980	1974	1973
	p	0.75	0.068	0.943	0.170	0.004	0.0001	0.042	0.012	0.001	0.476
	T1	10.814	0.776	11.269	20.048	12.475	2.265	-5.813	0.505	9.815	4.321
	T2	10.814	-0.776	11.269	20.048	10.671	3.875	-4.779	2.250	11.050	4.321
1991–2020	Mean (°C)	11.945	1.745	12.131	21.831	12.048	4.859	-3.931	2.766	12.766	5.148
	Kt	156	126	115	112	128	165	86	120	136	130
	tc	2006	2006	1998	2005	2007	2006	2012	1998	2006	2008
	p	0.001	0.02	0.044	0.052	0.015	0.0003	0.221	0.028	0.008	0.015
	T1	11.520	1.22	11.086	21.831	11.612	4.407	-3.931	1.514	12.247	4.582
	T2	12.400	2.307	12.464	21.831	12.667	5.343	-3.931	3.164	13.321	5.950

In the first half of the period (1961-1990) the test indicated a significant change point in average autumn temperatures in Kruševac, and average annual, winter, summer and spring temperatures on Kopaonik. The average autumn temperature in Kruševac and winter temperature on Kopaonik have a decreasing trend, while average annual, spring and summer temperatures in Kopaonik have a statistically important increasing trend.

In the first period (1961-1990), the trend is negative for average annual, spring and summer temperatures on both stations. The MK test indicated a non-significant decrease in the trend of annual temperature in Kruševac and a significant increase in the trend of annual temperature on Kopaonik. In the second half of the period (1991–2020) the test in both stations detects 2006 as a changing point of average annual and summer temperatures, 1998 as a changing point of annual spring temperature, and 2007 and 2008 as a changing point of annual autumn temperature. The average annual and seasonal temperatures in this period show a positive trend

in both stations. The MK test indicated a significant increase in temperature during all the seasons in Kruševac, summer and autumn on Kopaonik, with very high certainty (α=0.005–0.0001).The annual temperature exhibits an increasing trend from 0.5ºC/decade in Kruševac and 0.7ºC/decade in Kopaonik. The trend pattern indicated a significant increase in average annual, winter and summer temperatures in the whole series from 1961 to 2020. The statistically significant increase is also detected in spring in Kruševac and Kopaonik. The annual temperature for the Rasina river basin exhibits an increasing trend of annual temperature from 0.2ºC/decade in Kruševac and 0.7ºC/decade on Kopaonik.

Table 2. Man – Kendall test's statistic – Kruševac and Kopaonik temperature

Period		Kruševac							Kopaonik						
		Min.	Max.	Mean	St.dev.	Z	S	α	Min.	Max.	Mean	St.dev.	Z	S	α
1961–2020	T_{av}	10.0	13.20	11.36	0.81	5.46	0.03	***	1.4	5.9	3.9	1.27	-1.03	0.07	***
	W	-2.3	4.1	1.22	1.40	3.48	0.037	***	-6.9	-0.7	-4.7	1.38	4.61	0.05	***
	S_p	8.8	14.0	11.67	1.17	3.19	0.03	**	-1.1	5.6	1.9	1.48	5.30	0.06	***
	S_m	18.3	24.4	20.93	1.25	5.28	0.044	***	8.4	15.6	11.6	1.49	7.15	0.07	***
	A	8.5	14.7	11.61	1.24	2.35	0.023	*	0.8	7.8	4.7	1.44	2.25	0.02	*
1961–1990	T_{av}	10.0	11.6	10.81	0.43	-0.19	0.0	-	1.4	4.6	2.9	0.95	3.52	0.09	***
	W	-2.3	2.9	0.78	1.31	1.30	0.047	-	-6.9	-3.0	-5.3	1.13	2.76	0.08	**
	S_p	8.8	13.7	11.3	1.17	0.23	0.005	-	-1.1	4.0	1.1	1.34	2.10	0.06	*
	S_m	18.3	22.0	20.05	0.74	-1.13	-0.02	-	8.4	12.9	10.5	0.98	2.92	0.06	**
	A	8.5	13.1	11.17	1.27	-2.31	-0.07	*	0.8	6.3	4.3	1.57	-0.17	0	-
1991–2020	T_{av}	10.7	13.2	11.94	0.69	3.01	0.05	**	3.3	5.9	4.9	0.69	2.35	0.06	***
	W	-1.4	4.1	1.74	1.30	2.26	0.06	*	-6.5	-0.7	-3.9	0.02	0.77	0.02	-
	S_p	9.7	14.0	12.13	0.99	1.86	0.047	+	-0.1	5.6	2.8	1.13	2.35	0.06	*
	S_m	20.3	24.4	21.83	1.02	1.77	0.033	+	11.2	15.6	12.8	0.99	2.16	0.04	*
	A	10.0	14.7	12.05	1.09	2.86	0.060	**	2.8	7.8	5.1	1.22	2.69	0.09	**

Z–value of trend; S–Sen's slope; α – level of significance *** - α=0.001 ; ** - α=0.01; * - α=0.05; + - α=0.1

According to the used data the hottest year on the territory of the Rasina basin was 2000, while out of 10 hottest years, 9 have occurred since the year 2000. The hottest summer was during 2012, the same as on the territory of the whole Serbia (Vuković et al., 2018). The mean annual temperature for the period of 1991–2020 increased by 1.3°C with respect to the period of 1961–1989. The highest increase of 1.5°C, is recorded for the summer season. The season with the second highest increase in temperatures is spring.

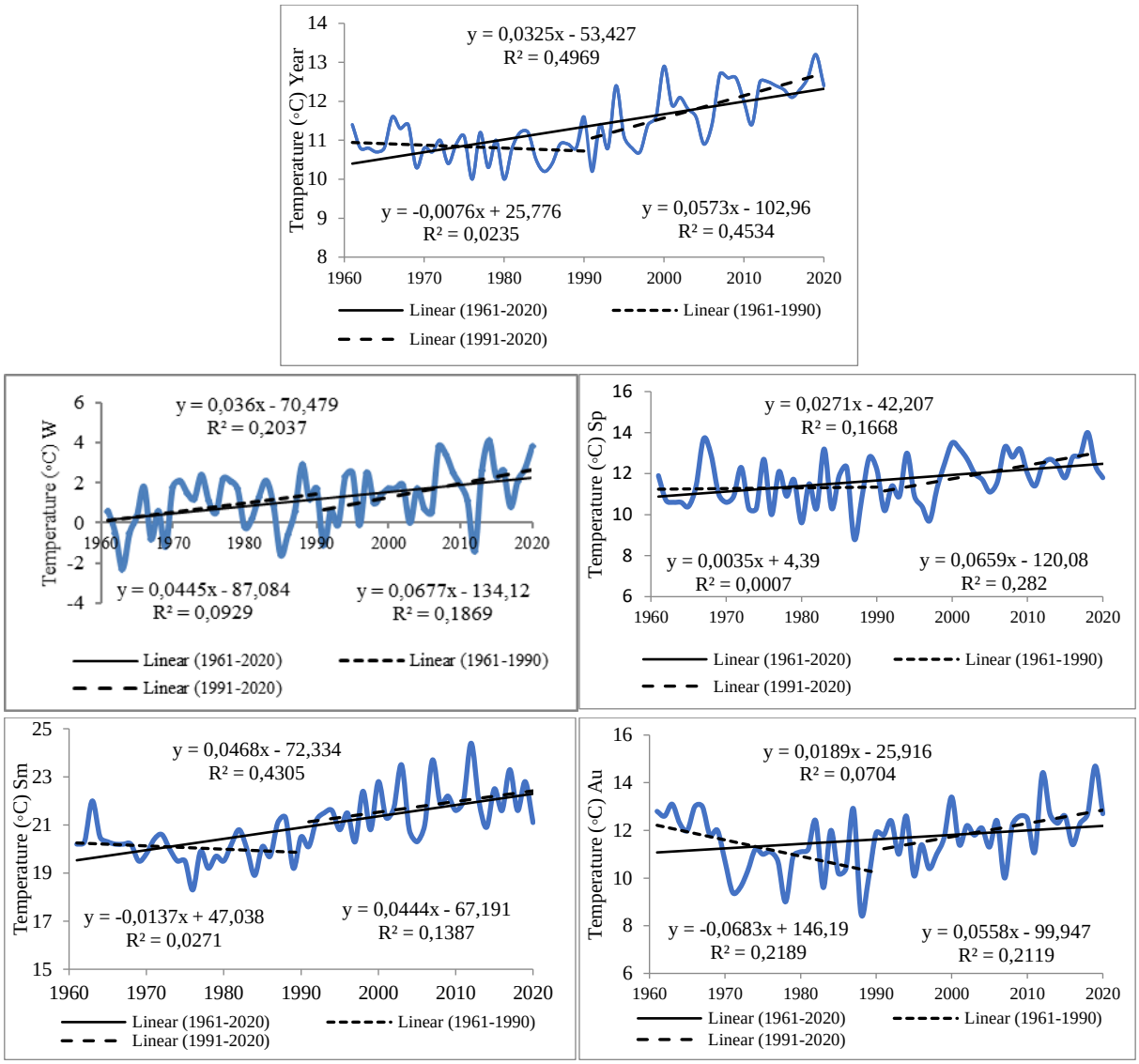

Figure 2. Average annual and seasonal temperatures, trend equations, and trend lines for Kruševac

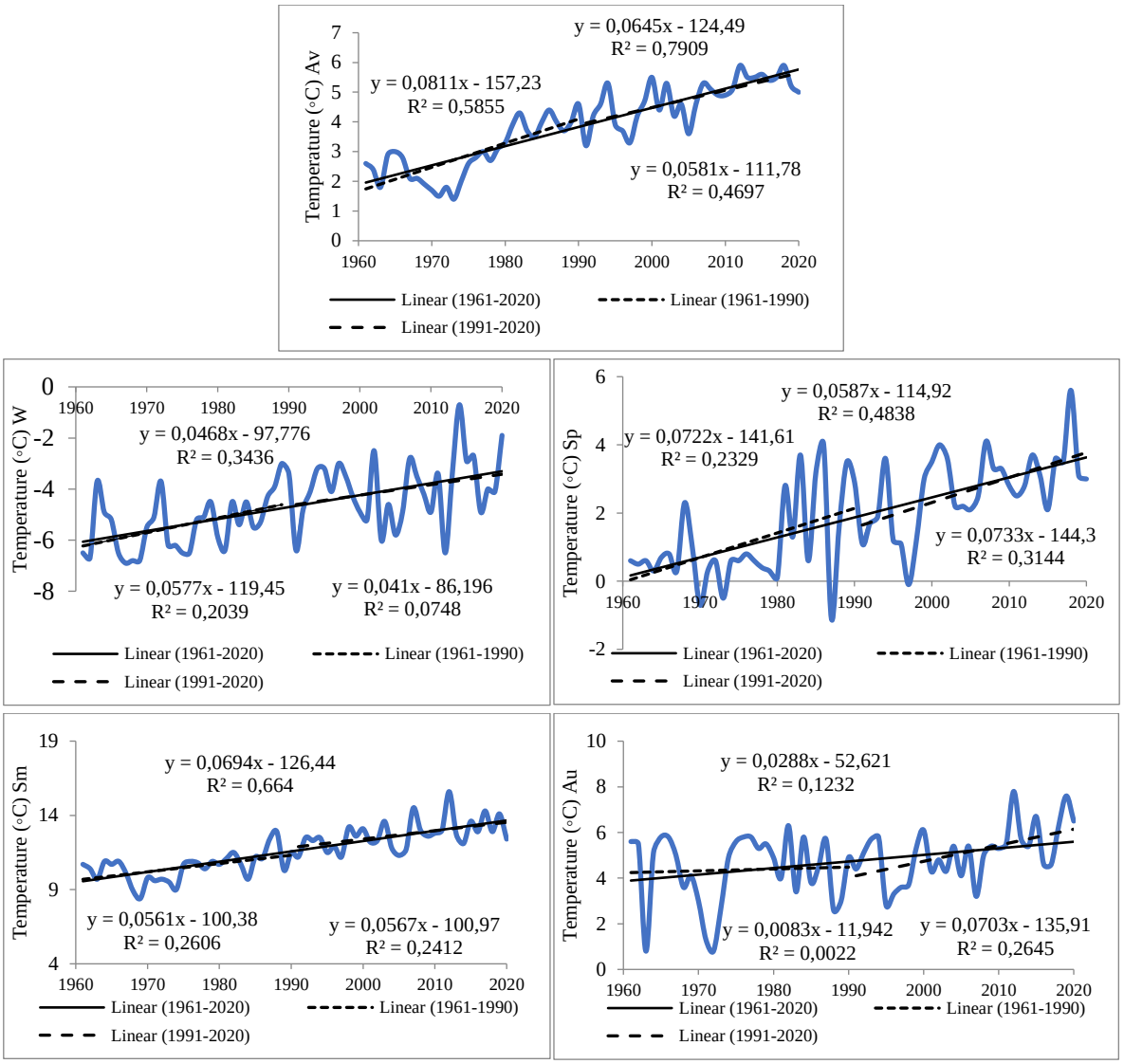

Figure 3. Average annual and seasonal temperatures, trend equations, and trend lines for Kopaonik.

Precipitation

In the period 1961–2020 a significant change point is observed on Kopaonik in annual winter and autumn precipitation. A change point in average annual precipitation was not detected. Average precipitations for the entire period are 651.1 mm in Kruševac and 999.9 mm in Kopaonik (Table 3). In the second period the average annual precipitation decreased for 2.1% in Kruševac, while in Kopaonik an increase of precipitation from 8.6% is detected.

The Mann-Kendal test reveals that the linear trend of total annual precipitation in the entire period is increasing and statistically significant on Kopaonik. In the first half of the period (1961–1990) Pettitt's test indicated a significant change point in average winter, summer and autumn precipitation on Kopaonik. In Kruševac the trend of average annual precipitation is increasing without statistical significance, while in Kopaonik it is decreasing, with statistical significance α=0.001. In the second period, a change point was not detected at any station. The linear trend of precipitation in the second period is positive and statistically significant at both stations (α=0.05).

Table 3. Pettitt's test statistic – Kruševac and Kopaonik- precipitation (mm)

Period	Variable	Kruševac					Kopaonik				
		T_{av}	W	S_p	S_m	A	T_{av}	W	S_p	S_m	A
1961–2020	Sum (mm)	657.1	139.5	180.2	188.8	148.6	999.9	195	287.5	296.5	216.3
	Kt	257	267	296	162	173	328	368	246	296	399
	tc	2002	2002	2003	1978	1969	1993	2002	2007	1969	1973
	p	0.218	0.188	0.112	0.744	0.67	0.06	0.024	0.268	0.111	0.014
	T1	657.1	139.5	180.2	188.8	148.6	999.9	178.5	287.5	296.5	154.3
	T2	657.1	139.5	180.2	188.8	148.6	999.9	235.6	-287.5	296.5	233.5
1961–1990	Sum (mm)	651.2	139.2	176.1	193.4	145.2	958.6	179.1	274.8	310.6	188
	Kt	82	52	52	74	79	62	124	110	128	112
	tc	1968	1969	1981	1964	1969	1967	1973	1966	1969	1972
	p	0.264	0.761	0.769	0.374	0.250	0.593	0.021	0.057	0.014	0.05
	T1	651.2	139.2	176.1	193.4	145.2	958.6	151.8	274.8	395.2	150.3
	T2	651.2	139.2	176.1	193.4	145.2	958.6	201.4	274.8	278.4	207.8
1991–2020	Sum (mm)	664.8	141.4	184.7	182.6	154.3	1040.2	212.8	298.9	281	361.3
	Kt	103	134	122	66	65	98	112	110	70	50
	tc	2002	2003	2010	2012	2017	2011	2002	2008	2014	2008
	p	0.092	0.009	0.024	0.5	0.593	0.115	0.051	0.054	0.43	0.80
	T1	664.8	113.9	159.1	182.6	154.3	1040.2	212.8	298.9	218.0	361.3
	T2	664.8	160.7	241.4	182.6	154.3	1040.2	212.8	298.9	281.0	361.3

Table 4. Man – Kendall test's statistic – Kruševac and Kopaonik precipitation (mm)

Period		Kruševac							Kopaonik						
		Min.	Max.	Mean	St.dev.	Z	S	α	Min.	Max.	Mean	St.dev.	Z	S	α
1961–2020	T_{av}	385.1	986.4	657.1	122.72	1.25	1.19	-	644.8	1444.8	999.9	155.22	2.09	2.50	*
	W	27.3	269.6	139.5	49.24	0.62	0.26	-	57.9	366.8	194.9	59.16	2.90	1.38	**
	S_p	69.3	378.9	180.2	64.54	1.05	0.56	-	89.9	536.5	287.5	75.61	1.36	0.88	-
	S_m	53.2	392.6	188.8	75.93	0.03	-0.02	-	113.8	533.9	296.5	98.64	-1.48	-1.1	-
	A	41.8	320.2	148.6	59.83	0.53	0.31	-	79.0	447.5	218.1	80.13	2.56	1.54	**
1961–1990	T_{av}	433.6	893.2	651.2	105.93	0.01	1.39	-	644.8	1178.3	958.6	131.30	-0.66	-1.65	***
	W	27.3	234.5	139.2	51.90	0.01	-0.62	-	57.9	265.2	179.1	53.04	0.01	2.83	*
	S_p	93.8	326.7	176.1	63.18	0.01	-1.06	-	89.9	409.1	274.8	73.53	0.01	-0.45	-
	S_m	88.5	322.8	193.4	68.85	0.01	0.45	-	140.3	508.4	310.6	97.28	0.01	-5.56	**
	A	47.8	264.9	142.6	55.84	0.01	1.16	-	79.0	344.3	187.9	62.99	0.01	2.08	-
1991–2020	T_{av}	385.1	986.4	664.8	140.6	2.03	6.42	*	736.9	1444.8	1040.2	170.86	0.01	2.21	*
	W	60.4	269.6	141.4	47.4	0.01	1.94	*	120.3	366.8	212.8	61.06	0.01	2.47	-
	S_p	69.3	378.9	184.3	66.65	0.01	1.11	*	193.1	535.5	298.9	78.07	0.01	2.67	+
	S_m	53.2	392.6	182.6	84.02	0.01	2.14	-	113.8	533.9	281.1	100.88	0.01	2.65	-
	A	41.8	320.2	156.1	64.24	0.01	-0.58	-	79.0	447.5	218.1	80.13	0.01	1.54	**

The winter season in Kruševac has a change point detected in 2003 in the second period. The average winter precipitations are slightly higher in the second period, with a significant linear trend. On Kopaonik the change point is detected in 2002, in the entire period, the linear trend is positive and statistically significant. In the spring season, both stations recorded an increasing trend in the entire period. In the second period, the change point was found in 2010 in Kruševac. The sum of precipitation increased from 159.1 mm to 241.4 mm. In the summer season there is a decrease in the mean value between the first and second period at both stations. The positive trend is detected in both periods in Kruševac and the second period on Kopaonik. There is a decrease in precipitation and a simultaneous increase in temperature at both stations in this period. The decrease in precipitation in this season is more pronounced on Kopaonik than in Kruševac. In the autumn season we found an increase in mean precipitation in the second period at both stations. On Kopaonik the change point is detected in 1973 during the entire period and the linear trend is positive with statistical significance α=0.01.

There is an increase in mean precipitation in the second period at both stations. There are no change points in any period, while the trend is slightly positive with statistical significance α=0.05 only on Kopaonik.

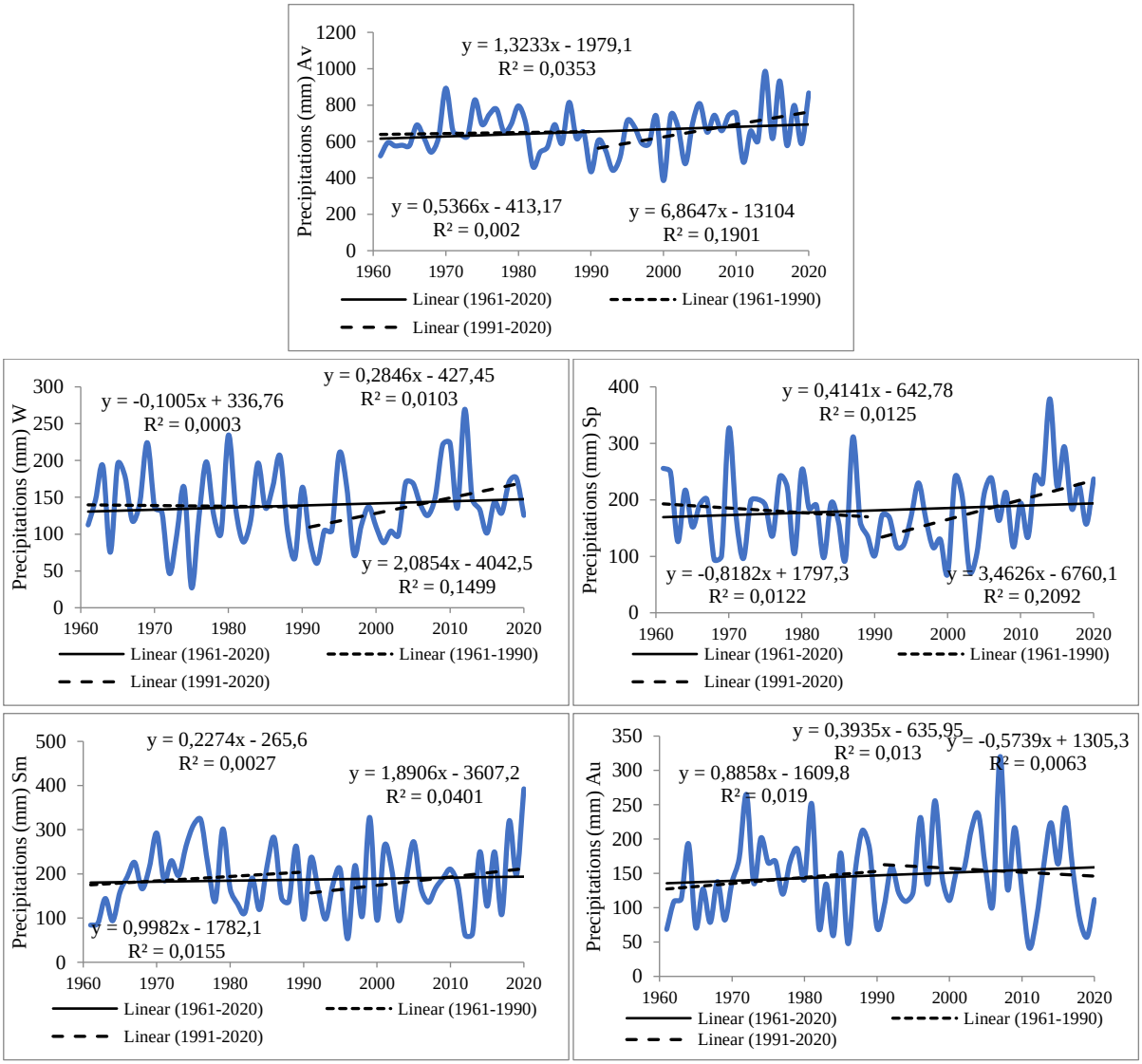

Figure 4. Average annual and seasonal precipitations, trend equations, and trend lines for Kruševac

According to the used data, the year with the highest sum of precipitation on the territory of the Rasina basin was 2014. The mean annual sum of precipitation for the period of 1991–2020 increased for 13.6 mm in Kruševac and for 81.6 mm in Kopaonik, with respect to the period of 1961–1990. The highest increase is recorded for the autumn season at both stations. The season with the second highest increase in precipitation is winter.

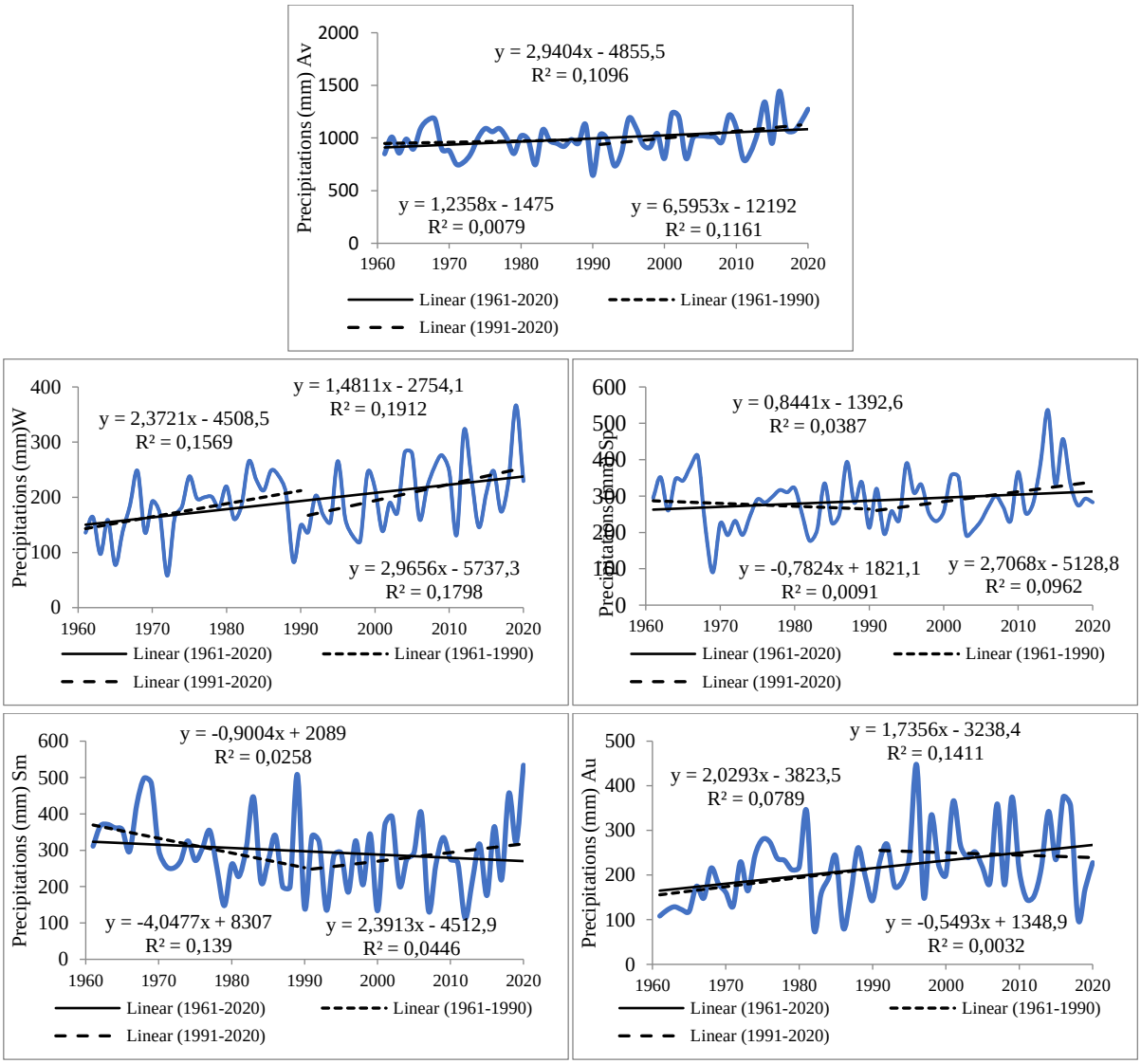

Figure 5. Average annual and seasonal precipitations, trend equations, and trend lines for Kopaonik.

Discharge

The average discharge of the Rasina in the entire period (1961–2020) in Brus is 2.41 m3/s and in Kruševac it is 7.36 m3/s, with a negative trend at both stations (Table 5). There is a change point in Brus in 1980, where the mean value of the discharge dropped from 2.82 m3/s to 2.21 m3/s. The mean value of the discharge is higher in the first period at both stations. In the second half of period there is a positive linear trend of increasing discharge without statistical significance. The analysis of trends of seasonal discharges at both stations showed that there were statistically significant changes in mean winter discharges in the whole period in Bivolje (α=0.05) and in average autumn discharges in the second period (α=0.1). In the winter season, there was a decrease in the mean annual discharge at both stations in the second period. In Brus, the average discharge was 10% lower in the second period, while precipitation was higher for 16%. The answer to this anomaly could be found in the period 1961–1990. In this period, there was a decrease in precipitation and an increase in temperature at Kopaonik stations. In the spring season, there is a trend of decreasing discharges in the entire period in the upper and in the lower course of the river, without statistical significance. In Bivolje, the average discharge

decreased by 4.5% in the second period, while at the same time, the increase in precipitation in Kopaonik was 8.1%. As there is also a positive trend of average temperature in Kopaonik, the most probable cause of additional discharge during this season comes from the late melting of snow accumulated during the winter season, primarily on Kopaonik. During the entire second period, there is a positive, statistically significant trend of increase in precipitation and temperature in Kruševac, which lead to a positive trend in the mean discharge in Bivolje. Even so, mean spring discharges in Bivolje dropped for 9.1% in the second period. The discharge trend throughout the summer season declined at both stations. The mean discharge in the second period is lower by 11.8% in Brus and 11.4% in Bivolje.

Table 5. Pettitt's test statistic – Brus and Bivolje- discharge (m^3/s)

Period	Variable	Brus					Bivolje				
		Q_{av}	W	S_p	S_m	A	T_{av}	W	S_p	S_m	A
1961–2020	Mean (m^3/s)	2.41	2.32	4.1	1.95	1.30	7.34	8.10	13.27	4.83	3.23
	Kt	409	316	204	280	268	315	447	185	199	226
	tc	1981	1980	1981	1979	1980	1981	1985	1981	1980	1980
	p	0.007	0.069	0.48	0.15	0.183	0.064	0.002	0.563	0.471	0.324
	T1	2.82	2.32	4.1	1.95	1.30	1.30	10.07	13.27	4.83	3.23
	T2	2.21	2.32	4.1	1.95	1.30	1.30	6.61	13.27	4.83	3.23
1961–1990	Mean (m^3/s)	2.53	2.49	4.20	2.04	1.38	7.79	9.38	13.24	5.07	3.44
	Kt	148	98	70	96	138	102	100	72	68	86
	tc	1981	1980	1970	1979	1980	1981	1980	1981	1977	1980
	p	0.002	0.119	0.437	0.131	0.007	0.096	0.107	0.408	0.468	0.220
	T1	2.82	2.49	4.20	2.04	1.69	7.79	9.38	13.24	5.07	3.44
	T2	1.88	2.49	4.20	2.04	0.70	7.79	9.38	13.24	5.07	3.44
1991–2020	Mean (m^3/s)	2.30	2.19	4.01	1.80	1.21	6.97	6.96	13.40	4.49	3.02
	Kt	68	72	58	70	76	90	65	89	67	66
	tc	2012	2009	2012	2016	2008	2002	1994	2003	2016	2006
	p	0.483	0.397	0.653	0.435	0.351	0.138	0.423	0.151	0.427	0.448
	T1	2.30	2.19	4.01	1.80	1.21	6.97	6.96	13.40	4.49	3.02
	T2	2.30	2.19	4.01	1.80	1.21	6.97	6.96	13.40	4.49	3.02

The discharge trend in the second period is positive at both stations. In the autumn seasons, the trend of decreasing discharge is most strongly expressed at both stations in the whole period and with statistically significant changes in the first period (1961–1990) in Brus. The decline in the mean discharge between the two observed periods is most pronounced in the winter season. In Brus, the discharge was 12.1 % lower in the second period, while in Bivolje it was lower by 25.8%. At the same time, we found that the average precipitation is higher by 1.8% in Kruševac and 8.1% in Kopaonik compared to the first period.

Table 6. Man – Kendall test's statistic – Brus and Bivolje-discharge (m^3/s)

Period															
		Min.	Max.	Mean	St.dev.	Z	S	α	Min.	Max.	Mean	St.dev.	Z	S	α
1961–2020	T_{av}	1.20	4.60	2.41	0.70	-1.49	-0.01	-	2.60	13.30	7.36	2.72	-0.94	-0.02	-
	W	0.95	4.46	2.32	0.81	-0.01	-0.01	-	1.82	19.33	8.10	4.05	-2.32	-0.07	*
	S_p	0.73	9.47	4.10	1.70	-0.56	-0.01	-	2.94	35.02	13.27	7.24	-0.16	-0.01	-
	S_m	0.40	4.58	1.94	1.11	-1.29	-0.01	-	1.26	14.19	4.83	2.93	-0.48	-0.01	-
	A	0.26	5.65	1.30	0.98	-1.10	-0.01	-	0.53	10.33	3.23	2.17	-0.94	-0.01	-
1961–1990	T_{av}	1.20	4.60	2.53	0.73	-2.51	-0.03	-	2.60	13.20	7.79	2.78	-1.58	-0.12	-
	W	1.38	4.46	2.49	0.89	0.01	-0.02	-	3.49	18.95	9.38	4.11	0.01	-0.12	-
	S_p	0.73	9.47	4.20	1.93	-0.01	-0.07	-	2.94	32.06	13.24	7.34	-0.01	-0.26	-
	S_m	0.62	4.55	2.04	1.03	-0.01	-0.03	-	1.33	14.19	5.07	3.03	0.01	-0.03	
	A	0.35	5.65	1.38	1.17	00.1	-0.02	+	0.65	10.33	3.44	2.46	-0.01	-0.02	
1991–2020	T_{av}	1.20	3.74	2.30	0.69	0.96	0.02	-	2.80	13.30	6.97	2.67	1.82	0.10	
	W	0.95	3.58	2.19	0.70	-0.01	-0.01	-	1.82	19.33	6.96	3.60	0.01	0.04	
	S_p	1.60	8.16	4.01	1.50	0.01	0.02	-	4.41	35.02	13.40	7.37	0.01	0.20	-
	S_m	0.40	4.58	1.80	1.20	0.01	0.02	-	1.26	14.16	4.49	2.86	0.01	0.07	-
	A	0.26	3.21	1.21	0.77	-0.01	-0.01	-	0.53	8.54	3.02	1.88	-0.01	-0.04	

Z–value of trend; S–Sen's slope; α – level of significance *** - α=0.001 ; ** - α=0.01; * - α=0.05; + - α=0.1

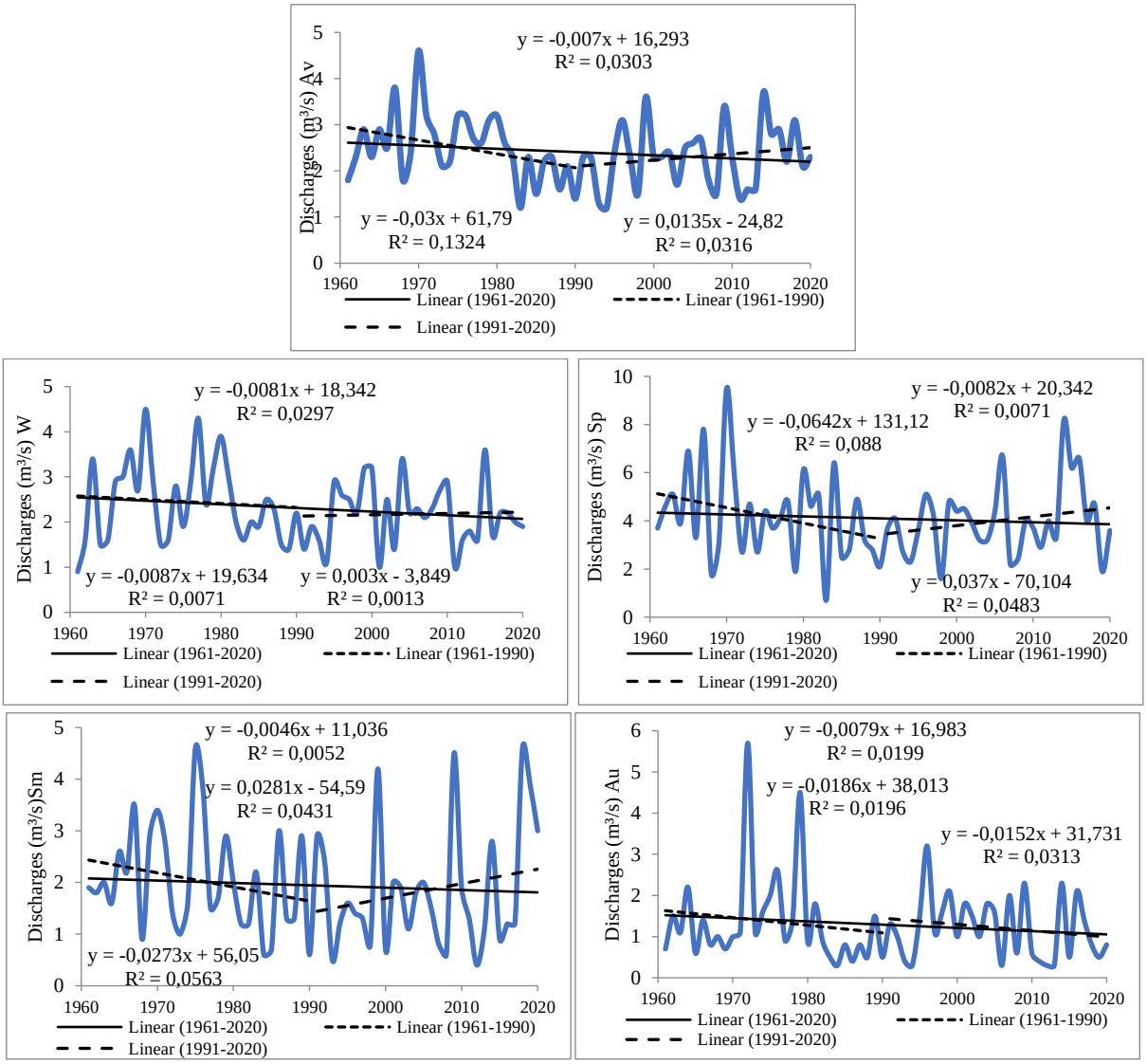

Figure 6. Average annual and seasonal discharge, trend equations, and trend lines for Brus

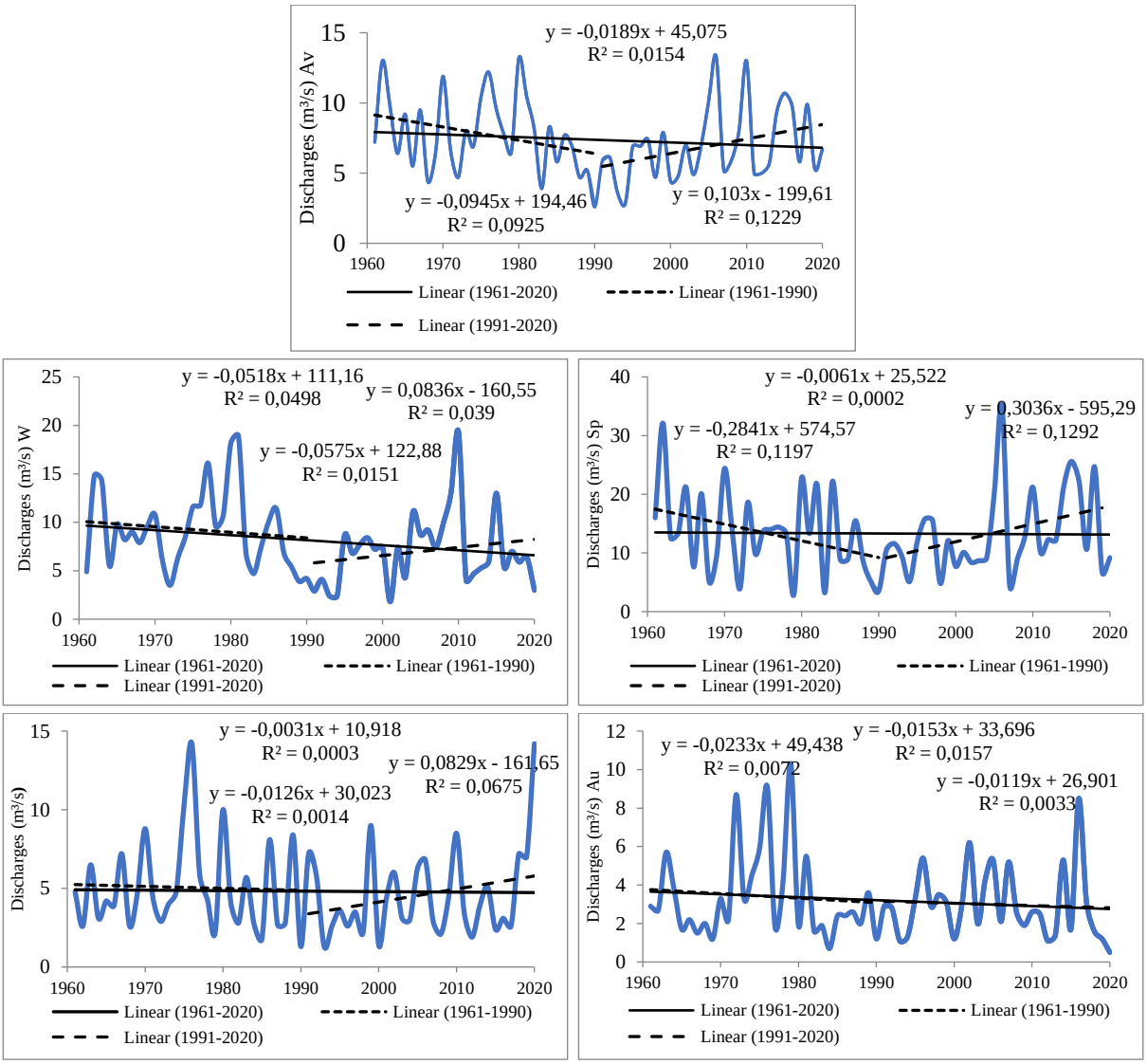

Figure 7. Average annual and seasonal discharge, trend equations, and trend lines for Bivolje

CONCLUSION

In this paper, long-term changes and trends in temperature, precipitation and discharges in the last 60 years in the Rasina River Basin were analyzed. Based on the statistical tests used, it can be concluded that there is a change point marking the occurrence of an increase in the average annual air temperatures in 1995 in Kruševac and 1984 on Kopaonik. The analysis indicated that the average annual, winter and summer temperatures, have significantly increasing trends in the longer period (1961–2020) and the second part of the period 1991–2020. In the period 1961–2020 a significant change point is observed on Kopaonik in annual winter and autumn precipitation. In Kruševac the trend of average annual precipitation is increasing, while in Kopaonik it is decreasing. In the second period, a change point was not detected at any station. Mean annual and seasonal average values of discharge at both stations are in all cases lower in the second period, except in the Sp season in Bivolje. In the W season, at both meteorological stations, there is an increase in the mean precipitation and temperature in the second analyzed period and a simultaneous decrease in discharge. The discharge trend throughout the summer season declined at both stations. In the spring season, there is a trend of decreasing discharges

in the entire period in the upper and the lower course of the river, without statistical significance. In the autumn seasons, the trend of decreasing discharge is most strongly expressed at both stations in the whole period and with statistically significant changes in the first period (1961–1990) in Brus. The river discharge regime in the Rasina River basin is strongly dictated by climate variability. Along the climatic factors, the use of water has also influenced the dominant decreasing trends in discharge values, especially because of the water supply of the settlements of the Kopaonik region (Paljevštica system) in the upper part of the basin and "Ćelije" system for water supply in the middle part of the river basin.

This study provides detailed information of trends in hydroclimatic variables in the Rasina River basin during recent decades, which is useful for future regional and local planning and integrated utilization of water resources.

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