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Analysis of River regime and Water balance of the Temštica River Basin (South-East Serbia) during the 1980-2012 Period

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Abstract

In this study we analyze river regime and water balance of the Temštica River on the base of thirty three year (1980 – 2012) data series. For this study period, the mean water level of the Temštica River was 41 cm. The average discharge of the Temštica River at Staničenje station for the investigated period is 5.63 m^3/s. Annual changes in average discharge is similar to the annual course of mean monthly low and high discharge values. It is concluded that the Temštica river has moderate - continental river regime. Although the precipitation quantity is not so low - 596 mm per year, of which 217.05 mm or 36.42 % of it runoffs, and 378.92 mm, or 63.58% evaporates. The ratio of the components of the water balance in the basin is not convenient, appropriate measures to improve the situation in this river basin should be taken.

Keywords: *Temštica river, water balance, water discharge, water level*

Rezumat. Analiza regimului și bilanțului hidrologic în bazinul râului Temstica (sud-estul Serbiei) în perioada 1980-2012

Articolul analizează regimul și bilanțul hidrologic al râului Temštica pe o perioadă de 33 de ani (1980-2012). Pentru această perioadă, nivelul mediu al râului Temštica a fost de 41 cm. Debitul mediu al râului la stația Staničenje pentru perioada analizată a fost de 5,63 mc/s. Schimbările anuale în debitul mediu urmează variațiile anuale ale debitelor minime și maxime lunare. În concluzie, regimul hidrologic al râului Temštica este unul continental moderat. Deși cantitatea de precipitații nu este foarte redusă – 596 mm/an, din care 217,05 mm sau 36,42% se infiltrează și 378,92 mm, adică 63,58% se evaporă, raportul dintre componentele bilanțului hidrologic al bazinului este deficitar, fiind necesare măsuri pentru îmbunătățirea situației în acest bazin hidrografic.

Cuvinte-cheie: *râul Temštica, bilanț hidrologic, debit de apă, nivelul apei.*

Introduction

Water balance is the flow of water determined as the surplus between input water and output water of watershed, region or waterbody within a period. Water balance is the basic principle of hydrology and water resource. Research on water balance has important theoretical significance and practical value (Xu, et al, 2009). The water balance equation is the basic hydrological model and it is widely applied to many fields (Darren et al., 2003; Yang et al, 2009). Precipitation, evaporation and runoff are the three main aspects in the water cycle process of river basin. For the river basin, water balance is the calculation basis of analyses of hydrology and water resources and effectiveness of water and soil conservation. However, water cycle process is affected by some complex factors such as climate, land surface conditions and human activities. Then we cannot collect enough information to get accurate values of the quantities of precipitation, evaporation and runoff. So the water cycle system of river basin is a grey one (Li et al, 2012). By using the correct investigation methods, we can get their number-covered sets (Yang et al, 2009; Li, 2009).

In the extensive international literature on trends in water levels, river flows and discharge changes in seasonal river flow regimes have been widely reported, for example in the USA (Novotny and Stefan, 2007; Hodgkins and Dudley, 2006), Canada (Khaliq et al., 2009; Burn et al., 2010), Switzerland (Birsan et al., 2005), the Nordic region (Wilson et al., 2010), and the Czech Republic (Fiala et al., 2010) and United Kingdom (Hannaford and Buys, 2012).

The aim of this study is to characterize the change in annual and seasonal water levels and discharge regimes of the Temštica River, throughout the full range of flows, including indicators of both high and low discharges as well as determining water balance characteristics of catchment area.

Study area

The Temštica River Valley in Pirot County on the southwestern slopes of the Stara Planina Mountain is a specific composition rich in natural habits of numerous plant and animal species (Stojsavljević et al., 2011).

The Temštica is the largest tributary of the Nišava River. The mouth of the Temštica River is near the village Staničenje, 16 km upstream from Pirot, about 95 km from the mouth of the Nišava into the Južna Morava River (Mustafić, 2006). The Temštica River is made of the Toplodolska River that springs just below the highest peak of the Stara planina (Midžor, 2168m) and the Visočica River which originates in Bulgarian, part of Stara Planina Mountain. The confluence of these two rivers is near the place called Mrtvački most at the altitude of 483 m. The surface of Temštica River basin is 818 km^2 (Gavrilović & Dukić, 2002).

Surlica (883 m), Sokolovica and Boloslavica, are the hills that overlook the left bank of the Temštica River, while Gradiste (843 m), Tumba and Temac (523 m) can be seen on the right bank. There are also four meanders of the Temštica River which can be seen downstream from Mrtvački Bridge. The largest tributary is the river Klajča which flows into the Temstica near Temska village (Stojsavljević et al., 2011).

One of the main characteristics of the Temštica River basin is a large decline in longitudinal profile of riverbed, at its thirty kilometers of length, from the base of Midžor peak and the altitude of about 1300 meters to Temska village, river overcomes a height difference as much as 1000 meters. For this reason, the flow is composed of a multitude of small and large eddies, rapids and waterfalls (https://sites.google.com/site/stanicenjers/).

In Serbia there can be indentified three basic climatic areas. Within each climatic areas there are specific sub-areas which are marked with A, B and V. The area of the Temštica river belongs to A climate. This climatic area, for the most part, would have continental climate characteristics (Rakićević, 1980). The south border is connected to the Nišava River and West Morava river to the Drina River (north-west of Užice). Landscape of the Temštica River more specifically includes sub-areas labeled as A-2-v. This area includes Svrljiške Mountains and Stara Planina Mountain. In the "1200 – 1800m" zone, there is belt of cold and snowy boreal mountain climate with average annual temperatures of 4 to 7°C and 950-1100 mm of precipitation. In Pirot and Dimitrovgrad, at the foot of the mountain, autumn is warmer than spring (Ducić, Radovanović, 2005a).

The overview of the researches of climatic and hydrological characteristics of analyzed area includes works of J. Petrović (2000), N. Živković (1998), V. Ducić and associates (2003; 2005b), B. Milovanović (2010), S. Mustafić (2006; 2007). When climate of the area is concerned, the most reliable data can be found in climatic annuals published by the Republic Hydrometeorogical Service of Serbia (Stojsavljević et al., 2011).

Material and methods

In this paper database of the Republic Hydrometeorological Service of Serbia for the 1980 – 2012 period for Staničenje hydrological stations was used to present variations in water levels and average amount and seasonal distribution of discharge in the investigated river flow. Because there is no climatological station in the Temštica river basin the interpolation of data obtained from three representative stations (Dimitrovgrad, Pirot and Bela Palanka) were used. Precipitation quantities were obtained on a monthly level for a period of 33 years (1980 – 2012) so every station had 396 parameters. For the stations taken into consideration, less than 20% of the data needed were missing. For the calculation of monthly precipitation over the Temštica River basin, the interpolation method was used.

Brickners water balance equation was used (Kovačević-Majkić, 2008).

$$P = Y * \mathrm{E} \quad (1)$$

Where P – precipitation, Y - total runoff and E – evaporation.

For calculation of specific runoff the following formula was used:

$$q = \frac{\mathrm{Qx1000}}{\mathrm{P}} \quad (2)$$

Where q - specific runoff, Q - discharge (m3/s), P - surface of river basin

Total volume of runoff (W) was calculated:

$$W = Q * T$$

Q – average discharge in research period, T – research period in seconds.

Total height of runoff was calculated according to:

$$h = \frac{\mathrm{W}}{1000 * \mathrm{P}}$$

Where h - total height of runoff, W – total volume of runoff in research period, P – catchment area (Dukić & Gavrilović, 2008).

Assessments of change in hydrological datasets typically employ statistical significance testing to detect trends. Whilst significance testing is an important aspect of formal detection and attribution, there are many factors which must be considered in interpreting statistical significance, e.g. choice of testing method, impact of multi-decadal variability, serial and spatial correlation, long-term persistence. Trend testing is therefore a contentious area, and the literature abounds with discussions on the utility (or otherwise) of statistical tests for trend (see Svensson et al., 2006; Clarke, 2010) (Hannaford and Buys, 2012).

Seasonal river flow indicators were computed for the following widely-used monthly groupings: winter (December–February), spring (March – May), summer (June – August) and autumn (September – November).In addition, the seasonal mean flow was

computed, as seasonal average flows are widely used in water research and management (Hannaford and Buys, 2012).

Results and discussions

Water level

As it can be seen in figure 1, the water level for the 1980 – 2012 period is variable. During the 1980 – 1990 period, we have the average high water level of 52 cm, while in the 1990 – 2005 period, we have a relatively uniform water level, an average of 40 cm. There is one exception, a sharp rise of 74 cm in water level in 2005, which represents the highest water level during the observed period. Our study shows that this peak is not due to precipitation because only 632.63 mm was recorded during that year in the Temštica river basin, this means that the rise in water levels is caused by other factor, most probably the higher water discharge from Zavoj lake which is situated on the Visočica river. Unfortunately we were not able to obtain data of water discharge from Zavoj lake for the observed period.

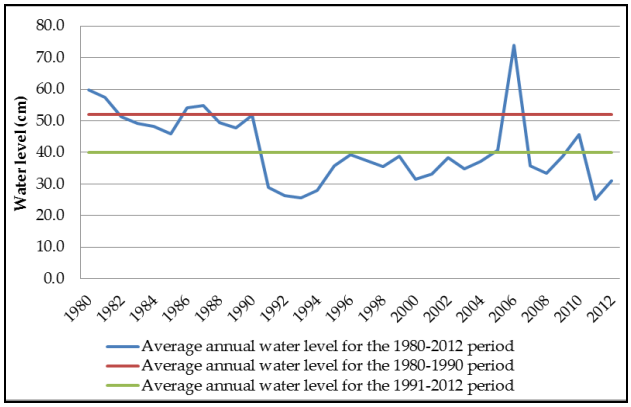

Fig. 1: The average annual water level for Temštica River during study period

The mean water level of the Temštica River was 41 cm and the lowest mean monthly water levels were recorded during September (26 cm), while the maximum mean monthly water levels were recorded during April (67 cm) for the 33 year period of observation.

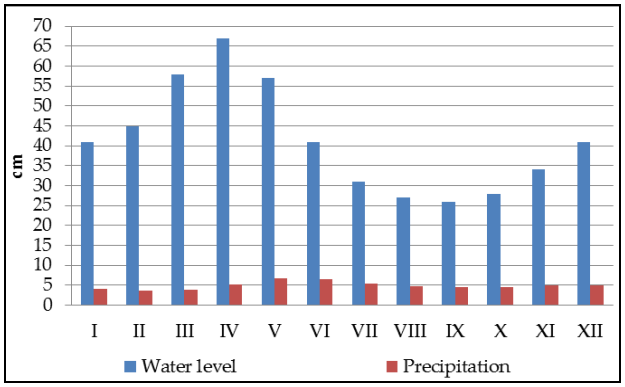

Fig. 2: Monthly values of the Temštica River water levels and precipitation for the 1980 – 2012 period

For the figure 2, precipitation values were recalculated into centimeters (cm). Comparing the mean monthly precipitation in the area of the basin and the mean monthly water levels (Fig. 2), we can conclude that they partially coincide and that the precipitation have significant influence on the water level.

Although the maximum mean monthly water level (April) and maximum mean monthly precipitation (May) does not coincide, they follow each other.

During the first half of the year data shows an increase in precipitation and consequently increase the water level, while during the second half of the year there is a decrease in water level due to the smaller amount of precipitation and higher evaporation.

Observing by seasons, the highest water level has been registered in spring and summer due to increase in the air temperature and partial snow melting. The water level decreases from April up to September even above the maximum precipitation in May and June when it was 67.82 mm and 65.81 mm. The lowest water level is at the end of summer and the beginning of autumn (Fig. 2).

Table 1: Average low and high monthly water levels of the Temštica river in cm (1980 – 2012)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average
ML WL	29	32	40	48	37	27	23	21	20	22	24	28	29
MH WL	69	79	100	119	119	80	57	52	43	52	71	81	77

As for annual value of the mean low and high water level, annual values were 29 cm (minimum) and 77 cm (maximum) and the average water level amplitude was 48 cm. The lowest value of the mean low water level throughout the year has been 20 cm recorded at the beginning of autumn (in September), whereas the highest values of the mean high water level were in April (48 cm).

River discharge

Average discharges are statistically derived mean values, which are often used in practice during the analysis and the making studies for the economy. However, these data will be processed in the work in order to obtain better picture of the regime Temštica River (Milanović, 2007). In hydrologycal research hydrographs of mean monthly flow values are often

used because they are easiest to provide, process and to explain. In this study the mean monthly flow for the 1980-2012 period was used, average monthly data was used to create the hydrograph which represents the annual river discharge of the Temštica river for the observed 33 year period (Fig. 3).

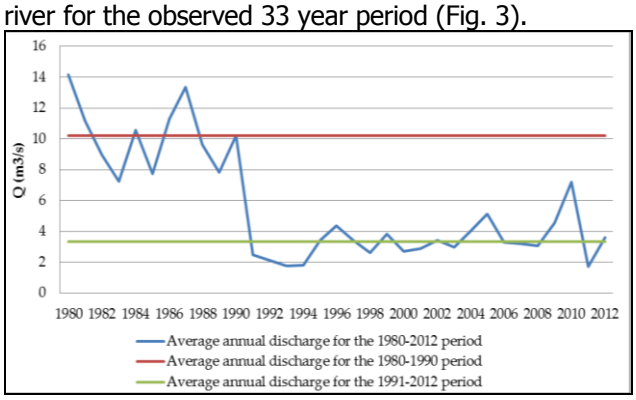

Fig. 3: Average annual discharge for the Temštica River during the study period

During the 1980 – 2012 period the average yearly discharge of the Temštica River clearly shows a disproportion between the first decade of the research period (1980 – 1990) and the rest of the period. During the first period, the average discharge value was 10.19 m^3/s, while the average precipitation for this period was 571.9 mm. During the rest of the period discharge values were lower, 3.34 m^3/s and the amount of precipitation was higher 608 mm. This observation is interesting because it indicates that some other factor, rather than precipitation has bigger influence to the river discharge. Most probably, the amount of water released from Zavoj lake that is located on Visočica River, one of tributaries of Temštica River. Monthly values of discharge for researched river are presented in figure 4.

In figure 4 we see that highest discharge on the Temštica River is during the spring months (March, April and May), on average 12.08 m^3/s, which represents 53.68 % of the total yearly discharge. Lowest discharge is observed during autumn (September, October and November), 2.16 m^3/s which represents 9.6% of the total yearly discharge. The highest discharge is measured during April (14.79 m^3/s). From this month the discharge starts to decline and reaches its minimal value during September, 1.38 m^3/s, after this minimum discharge starts to rise steadily till April. The average yearly discharge for the Temštica River during the investigated period is 5.63 m^3/s.

From this data we can conclude how much the discharge value is during "average" or normal years, with absence of extreme events like extreme precipitations or temperatures.

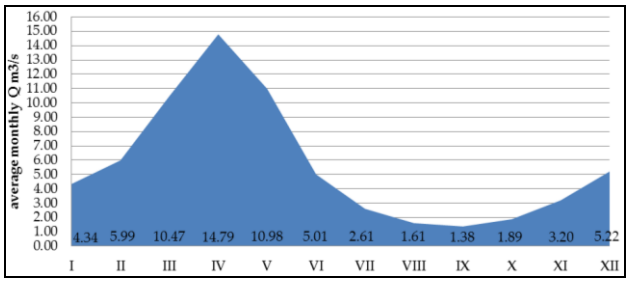

Fig. 4: Monthly variations with average monthly values of the Temštica River discharge for the 1980 – 2012 period

Maximum and minimum discharge

According to the data obtained from Staničenje hydrological station during the 1980 – 2012 period, the average annual minimum discharge was 2.18 m^3/s, while the average annual maximum discharge was 21.85 m^3/s. Amplitude between the average minimum and maximum discharge is 19.67 m^3/s. Minimum discharge had highest values in 1980, 5.82 m^3/s and the lowest in 1994 with 0.64 m^3/s. Higher discharge arise from precipitation and occur in waves and therefore more vary in relation to the small waters that depend on the groundwater flow (Milanović, 2007).

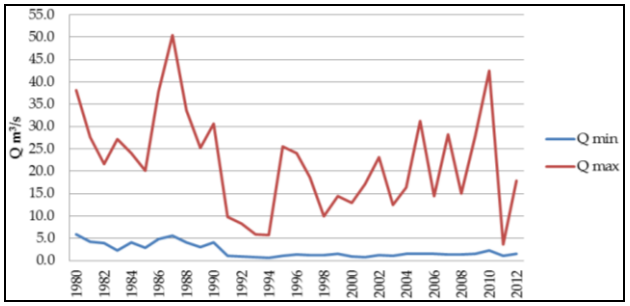

Fig. 5: Average annual values of minimum and maximum discharge of the Temštica River during the 1980 – 2012 period

In figure 5 it is noticeable that high waters had a lot of variations' during the observed period. The highest values of discharge were recorded in 1987 when it was 50.40 m^3/s, while the lowest values were recorded during 2011, 3.63 m^3/s.

Minimum discharge has higher values during the 1980 – 1990 interval (Q=4.01 m^3/s), while from 1991 to 2012 the minimum discharge was quite uniform, averaging less than 1.24 m^3/s

We can also notice is that in 1987, the minimum and maximum discharge values had their highest values for the observed period (Q_{min}=5.56 m^3/s, Q_{max}=50.40 m^3/s). The reason for that are the higher amount of precipitation recorded in the same year, 656.3 mm. The second peak is observed in 2010 when Q_{min} was 2.25 m^3/s and Q_{max} was 42.42 m^3/s, the reason for this peak is also the higher amount of precipitation during that year, 793.8 mm.

Precipitation

Average precipitation quantity in the Temštica River catchment for the 1980 – 2012 period, is 596 mm and it is well distributed throughout the year. The highest amount of precipitation falls during summer 55.65 mm (27.63%), slightly less in the spring, 53.37 mm (26.50%), in the autumn of 47.69 mm (23.68%), and during the winter, only 41.96 mm (20.83%) (Fig. 6).

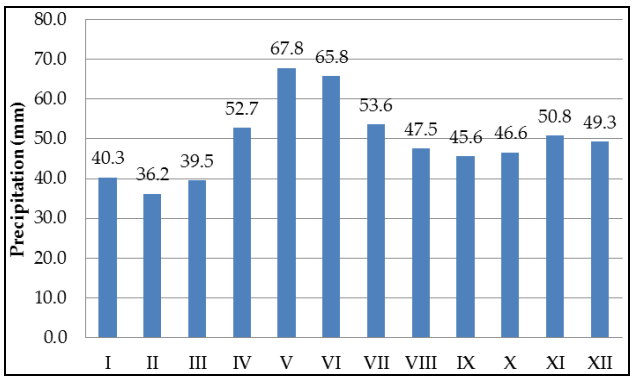

Fig. 6: Average monthly precipitation for the 1980 – 2012 period

High evapotranspiration caused by high air temperatures during time of maximum rainfall occurring in June, is the main reason for the divergence between rainfall and discharge peaks.

Specific runoff

Based on data from Table 2, it is noted that the values of specific runoff are small. Significantly increase values of the specific runoff are recorded from February till April, when the maximum of 18.07 l/s/km^2 is recorded, as a result of an increase in the amount of precipitation throughout the basin, while at the same time the air temperature is still low, and there is little evaporation. Decrease is measured during the warm period of the year (May – September), this is due to the minimal amount of rainfall and high air temperatures, which indicates extensive evaporation. From October till December increasing trend in specific runoff is observed (as a result of increased amounts of precipitation).

The general conclusion is that the low value of the specific runoff in the Temštica River basin is caused by climatic conditions (high evaporation), relief characteristics and anthropogenic influence (Milanović, 2007). In addition, the average and the absolute minimum and maximum values are important to be analysed. In the case of mean minimum and maximum specific runoff there was observed that the maximum runoff occurs in April, while minimum is observed during September (0.56 l/s/km^2) for the minimum value, and (7.74 l/s/km^2) for maximum value. Based on the calculated data of specific runoff, the height of runoff in the catchment area can be calculated, as well as runoff coefficient.

Table 2: Average, minimum and maximum monthly value of specific runoff (l/s/km²) of the Temštica River basin (1980 – 2012)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
q_{avg}	1.22	7.32	12.7	18.07	13.42	6.12	3.19	1.97	1.69	2.31	3.92	6.38
q_{min}	0.12	3.01	4.8	7.94	4.94	1.96	1.22	0.86	0.56	1.02	1.17	2.26
q_{max}	20.2	25.66	42.56	60.33	40.93	27.91	14.46	13.54	7.74	11.92	23.32	32.03

Water balance

Water balance of the Temštica River is shown based on the data obtained from Staničenje profile for the data relating to for the 1980 – 2012 period. Water balance is presented according to the relationship between rainfall at one hand and runoff and evaporation on the other (Table 3). Precipitation and runoff are based on the data measured and calculated, and the evaporation is calculated as a difference between rainfall and runoff (Milijašević and Milanović, 2010).

Water balance is the amount of available atmospheric, surface water and groundwater in a particular area, whether it is river or sea basin, a region or state territory. Knowing it is of great importance for water management and planning exploitation of water resources (Dukić, Gavrilović, 2012).

Table 3. Water balance of the Temštica River basin for the 1980 – 2012 period

Main elements of water balance						
Area (m2)	Discharge m3/s	Specific runoff (l/s/km2)	Precipitation (mm)	The amount of runoff (mm)	Evaporation (mm)	Runoff coefficient (%)
818	5.63	6.87	595.97	217.05	378.92	0.26

Water balance of Temštica River is presented as the relationship between rainfall on the one side and runoff and evaporation on the other side. Precipitation was determinate by interpolation of precipitation data obtained from three meteorological stations (Dimitrovgrad, Pirot and Bela

Palanka), and runoff data was obtained from measures taken at Staničenje hydrological station. Because there is no evaporation data measured in study area, the difference between precipitation and runoff was used to calculate evaporation.

Considering the Temštica River basin, with a catchment area of 818 km^2, it can be observed that the average amount of precipitation is 595.97 mm, of which 217.05 mm or 36.42 % runoffs, and 378.92 mm, or 63.58% evaporates. During the spring months the largest amount of precipitation flows as runoff, because air temperatures are still low, and evaporation reduced. Contrary to this, July, August and September represent the months with the lowest runoff of rainfall during the entire year because of higher evaporation.

Our research results have shown that within the basin of the Temštica River the average annual discharge is 5.63 m^3/s of water the richness of 6.87 l/s/km^2. Although precipitation is about 595.97 mm per year, lesser amount of it reaches the river, due to evaporation which exceeds 63%.

Conclusion

The analysis of the Temštica River discharge during the 1980 – 2012 period has shown that the maximum values are recorded during April, as a result of snowmelt, high soil moisture and frequent rains, and the minimum in September, due to high evapotranspiration and lower rainfall.

The water level analyses for the Temštica river in the 1980 – 2012 period have shown that the maximum values are registered in April (67 cm) as the result of snow melting and frequent rainfalls, and the minimum in September (26 cm) due to high evapotranspiration and less precipitation. The average water level amplitude is 48 cm for the 1980-2012 period.

Based on discharge data obtained at Staničenje station the existence of one maximum (April) and one minima(September) indicates a correlation between flow and precipitation in the basin. The amplitude of river discharge for the 1980 – 2012 is 13.31 m^3/s. According to the classification of river regime (Ilešič, 1947) it can be concluded that the Temštica River belongs to moderate - continental variant of hydrological regime. The amplitude between the average low and high water for the 1980 – 2012 period amounts to 20.61 m^3/s, and the amplitude of extreme flow are even more pronounced for the same period, from 3.63m^3/s in 2011 to 50.4 m^3/s in 1987 which represents an amplitude of 46.77 m^3/s.

The values of specific runoff for the Temštica River are low and are caused by climatic conditions (evaporation) and the low energy relief. Maximum values occur in March, as a result of an increase in the amount of rainfall throughout the basin, while at the same time the air temperature is still low, so evaporation values are also low. Minimum specific discharges are recorded in September, due to the low amount of precipitation and increased air temperatures, which indicate a larger evaporation.

In this paper, the components of the water balance of the Temštica River basin are calculated. Average annual precipitation for the entire basin is 595.97 mm, of which 36.52 % is the surface runoff, and 63.58 % is evaporated. The ratio of the components of the water balance in the basin is not convenient, and it should be taken appropriate measures to improve it (afforestation, hydrotehnical measure etc.

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Author contribution

This paper is the result of work done by Mirjana Radulović, she collected and analyzed the obtained data, Igor Leščešen helped with methodological part ad discussion, Dragoslav Pavić helped with expert advices and direction in which this paper should go.

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