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TRENDS OF MEAN ANNUAL AND SEASONAL DISCHARGES OF RIVERS IN SERBIA

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Abstract: Subjects of this paper are trends of annual and seasonal water discharges in Serbia. Data of water discharges at the 94 hydrological stations in the period 1961–2010 were analyzed, using the Mann-Kendall test and Sen's method. It was concluded that 27% of analyzed stations have statistically significant changes on annual level and 14–24% on seasonal level. The annual, winter, spring and summer trends are negative, while positive trends occur at only one station for annual values, on many stations in autumn and at a small number of stations in winter. Considering the quality of data, the results of the Beli Drim River basin require additional research, while negative trends at stations downstream of water reservoirs, primarily in basins of Južna Morava and Drina rivers, are consequences of human activities. Results show that the attention of the competent water management authorities should be directed to the Timok and Južna Morava basins in terms of the expected decrease of amounts of water, and to the basins of Toplica, Nišava, Pusta, Ibar and Kolubara rivers when it comes to increase of amounts of water.

Key words: discharge, annual trend, seasonal trend, Serbia, water resources

Introduction

Changes related to water resources - their quantity, quality, availability, and the risks associated with them - are topical issue worldwide. Regardless whether it is about growing number of casualties and material losses incurred due to high waters or increased water demands caused by the development of society, the question is whether we will be more frequently exposed to floods and whether there will be enough water. These are the questions science seeks answers for; detecting the causes of the changes and improving assessment of their impacts, while water management authorities are responsible for adequate (rational) solution of mentioned problems. Kovačević-Majkić, Urošev, Štrbac & Milanović Pešić (2013) emphasize the importance of preventive measures in water management in both *sensu stricto* and *sensu lato* sense, which means that contemporary water management involves a proactive approach (prevention) as

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opposed to the reactive approach that include response and recovery activities related to problems caused by water flows.

The dilemma, whether the risks of extreme hydrological events (floods and hydrological droughts) are increasing almost does not exist and the general goal is to reduce them. However, considering the fact that changes are complex process influenced by mutually interdependent factors, it is not easy to determine which of these factors and to what extent are affecting changes in water resources. It is certain that risk components (hazard, vulnerability and resilience) are variables which could be more (vulnerability and resilience) or less (hazard) influenced by human. In that sense and following the laws of Disaster risk management cycle (Wisner, Blaikie, Cannon & Davis, 2004), vulnerability and resilience could be influenced by adequate management of community (Gačić, Bošković & Raković, 2013) and thus reduce the risk. On the other hand, hazard is component on which man has limited effect, but contribution to risk reduction would be research of it. Most scientists do not deny the existence of changes in water resources (Arnell, 2002; Shiklomanov & Rodda, 2003, National Research Council, 2011; Hagemann et al., 2013; Gosling & Arnell, 2013) and they consider that changes of river regimes occur due to climate change (Stahl et al, 2010), but the subject of discussions are the determination of:

1. *Area in which changes occur (global, regional, local).* Many authors believe that the changes are taking place in the whole world and that all regions are more or less affected by them (Kundzewicz et al., 2007; Hagemann et al., 2013; Gosling & Arnell, 2013). These conclusions are based on the results of the Intergovernmental Panel on Climate Change (IPCC) on the basis of observed, as well as on the basis of projected changes (Hartmann et al., 2013). In these reports decrease of precipitation in parts of southern Europe is reported. Also, these scenarios of climate change in Southeast Europe suggest that these changes should be expected as well in Serbia, and predict the decrease of up to 50% by the year 2080 (Arnell, 2002), or 6 to 36% by the year 2070 according to Alcano et al. (2007). Hagemann et al. (2013) suggest that a significant reduction in flow is expected in central and southern Europe, or according to Stahl, Tallaksen, Hannaford & J. van Lanen (2012) in the southern and eastern regions of Europe. However, there are also experts cautious and skeptical about such views (Pielke, 1999; Cluis & Laberge, 2001; Dery & Wood, 2005 cited in Burić, Stanojević, Luković, Gavrilović & Živković 2012), while also in the report of the IPCC (Hartmann et al., 2013) it is stated that the decreasing trend of discharges in the 20th century has a low level of confidence. In Serbia, the expert community also disagrees on the fact whether we are affected by changes. One part of the scientific community proves that there are changes of meteorological parameters, especially the increase of average temperatures and

short-term heavy rainfall (Kapor et al., 2011), and although there is a decreasing trend of discharges, more frequently large scale floods could be expected (Dimkić & Despotović, 2012). The second part argues that the analyses of hydrometeorological data do not show this trend and that this especially can be claimed for areas in moderate geographical latitudes in which Serbia is located (Ducić, Nikolić & Dragićević, 2006; Ducić & Luković 2009; Burić et al., 2012).

2. *Time scale in which changes occur (annual, seasonal)*. In order to determine these changes numerous analyses of mean annual and mean monthly water discharge have been done. It was determined that changes occur mainly at the seasonal level (Stahl et al, 2010) and that the increased intensity and frequency of high waters shifts from spring to winter. Also, in many studies conducted throughout Europe, mentioned in Stahl et al. (2010), hydrological drought and water scarcity in summer have been recorded more frequently. In Serbia as well, it was determined that nowadays maximum discharges are recorded more frequently in winter, rather than in spring as it was before (Dimkić & Despotović, 2012).

3. *Direction in which changes occur (decrease or increase)*. Changes of the amounts of water resources in time are considered on the basis of their trend, which generally indicate a decrease of water amounts or reduction of usable water (Lehner, Döll, Alcomo, Henrichs & Kaspar, 2006).

4. *Significance of changes (significant or not).* While one part of authors believe that these changes are significant (Dimkić & Despotović 2012), the other part considers the changes as normal processes and that over a longer time period they represent random values and are segment of much longer natural cycle (Isailović & Srna, 2001).

5. *Causes that led to changes (natural and/or anthropogenic factors)*. There are great differences in opinions whether the climate changes and changes in water resources are the consequences of natural processes or human actions, primarily emission of carbon dioxide.

The subject of this paper is the trend analysis of mean annual and seasonal waters in Serbia. Average waters, expressed by the discharges, were selected as indicators of water resources, because as pointed out by Živković (2009) knowledge of them is essential for all aspects of water management and the definition of extreme water conditions in river. Questions that will be answered is whether the changes in discharges exist in Serbia and if they do, are they related to some or all rivers; whether the changes occur on annual or seasonal level; whether it's the case of decrease or increase of discharges; whether the changes are significant and on what level of confidence. The discussion will be guided by comparison with regional and national studies that already have been carried out. Unlike many studies which deal with causes of changes, the primary objective of this paper is not to find factors that led to changes, but to determine areas where changes occur regardless whether the rivers have a natural or artificial regime. The reason for this lies in goal of this paper, which is to determine areas with possible greatest impacts of existing changes, meaning to determine areas where sustainable water resources management should be establish.

Data and methods

Based on the published data of the Republic Hydrometeorological Service of Serbia (RHMSS), and in accordance with the set of goals, criteria for the selection of data from hydrological stations were defined and it included several selections (see figure 1). The first selection implied selection only of those stations which measure water discharge (Q). The second selection entailed choice of stations that had continuity in discharge measurements for at least 30 years within the studied period (1961–2010). For stations that have begun to work in 80s the period 1981–2010 was used, while for the stations in the Beli Drim basin data are available until 1995 and period 1961–1995 was used for calculation[2]. Data from nearby stations on Zapadna Morava river, Kratovska stena (1979–2010) and Gugaljski most (1961–1978), which is not in operation since 1978, have been merged into one time series, having in mind that difference in basin areas are negligible. At stations where measurements were not continuous, but these discontinuities were small, the data were filled using the proportions in relation to the station with whom they have the best correlation on monthly level. So the choice was reduced to 94 stations.. Only the station Prizren on the Prizrenska Bistrica River has non-continuous series of 20 years which was not possible to fill in a relevant way. However, as the only station that describes the hydrological condition of Šara mountain part of the Adriatic basin it is taken into consideration, regardless of set criteria, but these results must be interpreted cautiously with great uncertainty, particularly when it comes to trends.

Figure 1. Algorithm showing the selection of stations

Trend analysis of mean annual and seasonal water discharges was used for the interpretation of inter-annual variation in river flow. Nonparametric Mann-Kendall test was used to test the statistical significance of the trend of mean flows, as one that is not sensitive to outliers, which are typical for discharges. Although the confidence interval of 95% is good enough for data analysis on

[2] Nowadays RHMSS does not have data from Beli Drim basin (4639 km^2 basin area in Serbia)

annual level, in this paper we have also used confidence intervals of 90%, 99% and 99.9%. Thus, based on the level of significance of trend, i.e. the degree of confidence, we made a gradation of changes in discharges as shown in Table 1. For the estimation of trend slope Sen's method was used, which shows the change in the unit of time (in this case: $m^3/s/year$).

Table 1. Level of significance of trend

Significance	Level of significance	Confidence interval (%)	Level of significance α	Label
Without statistical significance	Without statistical significance	< 90	> 0.1	/
Statistically significant	Low significance	90	0.1	+
	Moderate significance	95	0.05	*
	Significant	99	0.01	**
	Very significant	99.9	0.001	***

As basin is the basic spatial unit for hydrological studies and water management, the territory of Serbia is divided into 11 major river basins. As part of the Black Sea basin, i.e. the Danube River basin, there are watersheds of Tisa, Sava, Drina, Kolubara, Velika Morava, Zapadna Morava, Južna Morava, Timok and the rest of the Danube basin. Data for the Danube River Basin without major tributaries, the Sava and the Tisa are summarized in figures. The other two sea basins are the Adriatic Sea basin, i.e. Beli Drim River basin and the Aegean Sea basin, which is not territorially continuous and consists of basins of Lepenac, Pčinja and Dragovištica rivers. The data in this paper are presented by these entities.

Results and discussion

When it comes to water potential of a territory, specific runoff is used more frequently than discharge, which according to the data that we had is 5.4 $L/s/km^2$ in Serbia. According to Ocokoljić (1993/94) the value of mean specific runoff in Serbia is 5 $L/s/km^2$, according to Manojlović and Živković (1997) 7.06 $L/s/km^2$and according to Prohaska (2003) 5.73 $L/s/km^2$. Nevertheless mean annual discharge was chosen as an indicator of water potential, whose values are shown in Table 2. According to data from 1961 to 2010 period Serbia has a total of 5565 m^3/s of water, which is the sum of water that flow out of Serbia (Danube, Beli Drim, Plavska reka, Lepenac, Pčinja and Dragovištica). At the same time the greatest amount of water in Serbia belongs to international rivers (transit waters) (Danube, Sava, Tisa, Drina, Lim, Begej, Tamiš), while only 481 m^3/s, i.e. 8.6% of water comes from Serbia (domicile waters). In “Serbia water master plan” period 1946–1991 was used (Prohaska, 2003) and the results for majority of station slightly differ from the results of our research. Studying the water regime in eastern Serbia, Ristić (2007) got similar values for studied period 1961–2000.

Table 2. Mean annual discharges (Q), level of significance of trend (α) (labels as in Table 1) and discharge change per year (S) (by Sen's method) on stations in Serbia

River	Station	Q (m^3/s)	α	S (m^3/s)	River	Station	Q (m^3/s)	α	S (m^3/s)
Dunav	1. Bezdan	2298	/	1.71	Kamenica	48. Prijevor	1.9	/	0.02
	2. Bogojevo	2806	/	-2.68	Čemernica	49. Preljina	4.0	/	0.00
Sava	3. Sr. Mitrovica	1523	/	-4.55	Ibar	50. Leposavić	29.7	/	-0.10
Tisa	4. Senta	806	/	0.10		51. Raška	38.9	/	-0.13
Mlava	5. Žagubica	1.8	/	-0.00		52. Ušće	44.4	/	-0.09
	6. Gornjak	6.5	/	0.08		53. Lop. lakat	55.3	/	-0.04
Pek	7.Kučevo	7.4	/	0.11	Sitnica	54. Nedakovac	12.0	/	-0.01
Šaška	8. Crnajka	1.4	/	0.01	Raška	55. Raška	7.2	/	0.03
Crnajka	9. Crnajka	0.6	/	0.01	Jošanica	56. Biljanovac	3.4	/	0.00
Drina	10. Radalj	332	/	1.54	Studenica	57. Ušće	7.0	/	0.02
	11. Bajina Bašta	328	**	-2.40	Gruža	58. Guberevac	1.2	/	-0.00
Lim	12. Brodarevo	70.0	*	-0.33	Rasina	59. Bivolje	7.4	/	-0.03
	13. Prijepolje	76.0	/	-0.29	J. Morava	60. Vl..Han	19.3	/	-0.04
	14. Priboj	91.1	**	-0.60		61. Grdelica	24.9	/	-0.08
Mileševka	15. Prijepolje	1.3	/	-0.00		62. Korvingrad	54.3	/	-0.31
Jadar	16. Lešnica	7.9	/	0.03		63. Aleksinac	86.4	*	-0.61
Kolubara	17. Slovac	9.5	/	0.01		64. Mojsinje	91.7	*	-0.54
Jablanica	18. Sedlare	1.4	/	-0.01	Vlasina	65. Vlasotince	7.8	*	-0.06
Obnica	19. Belo Polje	1.8	/	0.00	Veternica	66. Leskovac	3.9	/	-0.03
Gradac	20. Degurić	2.7	/	-0.00	Jablanica	67. Pečenjevce	4.1	*	-0.04
Ribnica	21. Paštrić	1.2	/	0.00	Pusta reka	68. Pukovac	1.6	/	-0.01
Ljig	22. Bogovađa	4.3	/	-0.02	Toplica	69. Pepeljevac	6.4	*	0.06
Peštan	23. Zeoke	0.6	/	-0.00		70. Doljevac	9.6	/	-0.05
Tamnava	24. Koceljeva	1.0	/	-0.00	Nišava	71. Dimitrovgrad	2.1	/	-0.01
Ub	25. Ub	1.0	/	-0.00		72. Pirot	12.6	/	0.04
V. Morava	26. Varvarin	203	/	-0.78		73. Bela Palanka	22.5	*	-0.19
	27. Bagrdan	215	/	-0.74		74. Niš	28.3	*	-0.23
	28. Ljubič. Most	230	/	-0.63	Jerma	75. Sukovo	5.3	/	-0.01
Crnica	29. Paraćin	3.5	/	-0.00	Temštica	76. Staničenje	7.6	***	-0.20
Ravanica	30. Ćuprija	0.7	/	-0.01	Visočica	77. Visoč. Ržana	5.2	***	-0.07
Lugomir	31. Majur	1.8	/	-0.01	S. Moravica	78. Žučkovac	2.3	/	0.01
Belica	32. Jagodina	0.6	/	0.00	Crni Timok	79. Bogovina	5.8	*	-0.06
Lepenica	33. Batočina	2.0	/	-0.01		80. Gamzigrad	10.0	/	-0.06
Resava	34. Man. Manasija	3.7	/	-0.01	Zlotska reka	81. Zlot	2.8	/	0.03
	35. Svilajnac	4.9	/	-0.01	Beli Timok	82. Knjaževac	8.0	*	-0.06
Jasenica	36. Sm. Palanka	1.8	/	-0.01		83. Vratarnica	9.8	*	-0.08
Z. Morava	37. Krat. stena	32.6	/	0.04		84. Zaječar	11.6	*	-0.24
	38. Jasika	104	/	-0.15	Svrlj. Timok	85. Rgošte	2.7	/	0.00
G. Moravica	39. Ivanjica	7.0	/	-0.00	Beli Drim	86. Kpuz	23.0	*	-0.27
	40. Arilje	10.6	/	-0.00	Klina	87. Klina	1.4	/	-0.02
V. Rzav	41. Roge	6.1	/	0.00	Peć. Bistrica	88. Peć-Klisura	5.8	/	-0.05
	42. Arilje	7.9	/	-0.01	Deč. Bistrica	89. Dečani	3.9	/	-0.03
Đetinja	43. Stapari	3.6	/	-0.00	Priz. Bistrica	90. Prizren	3.3	**	-0.05
	44. Šengolj	5.5	/	0.06	Dragovištica	91. Ribarce	3.1	/	0.00
Skrapež	45. Kosjerić	1.5	/	0.01	Ljubatska reka	92. Bosilegrad	1.3	/	0.01
	46. Požega	4.7	/	-0.01	Brank. reka	93. Ribarce	1.2	/	0.01
Bjelica	47. Guča	2.3	/	-0.02	Pčinja	94. Barbace	3.4	/	-0.01

Annual discharge trends

From 94 analyzed stations in Serbia, discharge increases at 32% of stations, and decreases at 68% of stations. At 73% of analyzed stations they are treated as normal random processes. The increase of discharge which is not statistically significant was recorded at 29 stations, while the decrease of discharge without statistical significance was registered at 40 stations. The remaining 25 stations (27%) had a statistically significant trend of mean annual discharge, which is negative at 24 stations and positive only at the station Pepeljevac on the Toplica River (Table 3).

Table 3. Trends of mean annual water disharges in Serbia

Level of significance	Positive	Positive (%)	Negative	Negative (%)	Total	Total (%)
/	29	91	40	43	69	73
+	0		7		7	
*	1	9	12	57	13	27
**	0		3		3	
***	0		2		2	
Total	30	32	64	68	94	100

Results of trends of mean annual discharges by river basins are shown in figures 2 and 3. At the top among the basins in which there was a significant decrease of discharges is the Južna Morava basin with 10 stations, followed by the Drina, Timok and Beli Drim (Adriatic) basins with four stations. Decrease of discharges in the river basins of Južna Morava and Timok can be explained by negative trend of precipitation but without statistical significance, which is analyzed in Stanojević (2012) for the eastern and south-eastern Serbia and Milovanović (2005) for Stara Planina mountain. In the Kolubara and the Velika Morava basin at one station on each basin was recorded a significant decrease, while in the basins of the Danube, Sava and Tisa, without above mentioned major tributaries, and in Zapadna Morava and Aegean basins there are no significant decrease of discharges on annual level.

More detailed analysis of significant negative trends, with exclusion of stations with data series less than 50 years, shows that very significant trend was observed on stations Staničenje and Visočka Ržana (the Temštica basin), and significant trend had Bajina Bašta and Priboj in the Drina and the Lim basin respectively. We should bear in mind that significant and very significant decreasing trends of discharges are registered on rivers with changed natural regime due to human activities (construction of water reservoirs), aimed at rational use of their water and flood protection. Kapor et al (2011) came to similar results. Moderate significance trends has Brodarevo on the Lim River and a number of stations in the basin of Južna Morava and Timok, while low significance trends are recorded at stations Sedlare on the Jablanica, Ćuprija on the Ravanica, Korvingrad on the Južna Morava and Leskovac on the Veternica rivers. At stations in the Adriatic basin, more precisely the Beli Drim basin, trends are questionable, considering the quality of the data (short data sets).

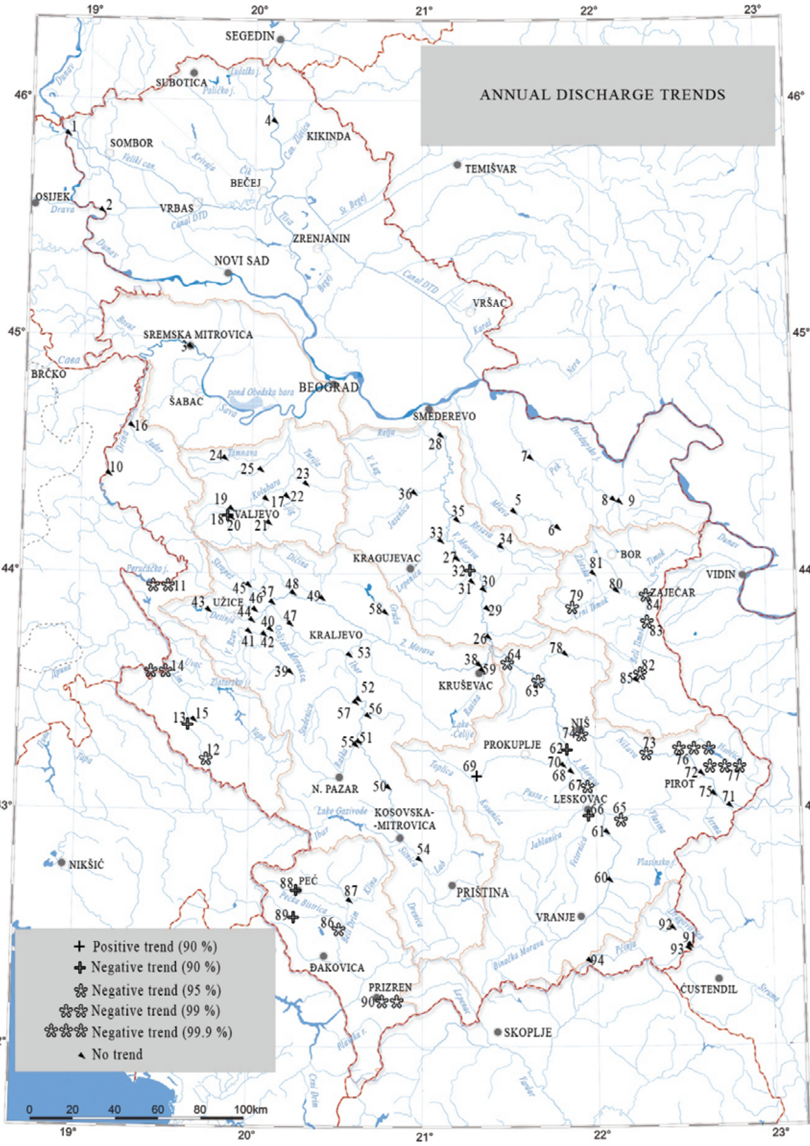


Figure 2. Spatial distribution of significant annual discharge trends in Serbia

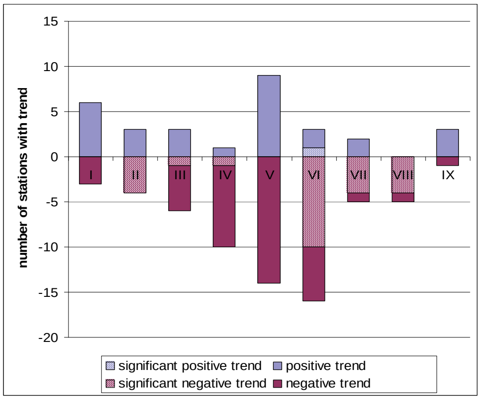


Figure 3. Annual discharge trends in Serbia by river basins
I – Danube, Sava and Tisa without major tributaries, II – Drina, III – Kolubara, IV – Velika Morava
V – Zapadna Morava, VI – Južna Morava, VII – Timok, VIII – Beli Drim, IX – Aegean basin

Based on the trend analysis of mean annual discharges at 35 stations Kapor et al (2011) concluded that there are no significant trends in the Danube River basin for rivers with natural regimes, but there are some decreasing trends as a result of anthropogenic impacts. They also have registered the largest number of significant trends in the basin of Južna Morava. Prohaska (2003) reported that the maximum decrease of discharges is on Lepenac, Temska and Beli Drim rivers, and the smaller increase on the Danube, Tisa, Južna Morava and Nišava rivers. Decrease at few stations in Serbia, where there are reliable data on the relatively long data series, was confirmed by Isailović & Srna (2001). The increase was noted only on the Tisa. They concluded that these changes are not significant, but could be alarming. Dimkić & Despotović (2012), based on trend analysis in eight catchments in Serbia of area less then 1000 km^2, showed that the average decrease of runoff in the next 100 years is expected to be 58%, which is higher than the IPCC prediction of 25–30% (IPCC, 2007 cited in Dimkić & Despotović, 2012). Also, they conclude that at stations with longer data series, larger discharges and basin areas, smaller decrease of discharges (15%) in the next 100 years is expected. They indicate that the changes of temperature are crucial for precipitation and discharge changes, and that the temperature changes of 2°C will lead to changes by 15% in rainfall and by 50% in discharges. Considering the fact that most of the rivers in Serbia, except for Beli Drim basin, belong to pluvio-snow regime, i.e. first of all largely depend on rainfall regime and then on snow melting, this scenario should encourage the search for solutions. Stojković, Plavšić & Prohaska (2012) by analyzing a series of mean annual discharges on the Danube River, also concluded that the stations on the Danube River in Serbia have a significant decrease of discharges with confidence interval of 95%.

Seasonal discharge trends

Seasonal discharge trends show that a statistically significant trend was observed at the majority of stations in autumn (24% of stations), while in other seasons significant trend was recorded on 14–15% of stations (Table 4). In winter, on almost equal number of stations decrease and increase of discharges was present. In spring only on a single station significant increase was recorded, while in the summer there were no increases, while discharges decreases at 13 and 14 stations respectively. In autumn situation is opposite, particulary at 20 stations significant increase of discharges was recorded and decrease at three. On other stations (76–86% of analyzed stations depending on the season) there are changes of discharges, but not statistically significant.

Table 4. Seasonal discharge trends in Serbia

Season	Level of significance	Positive	Negative	Total	Total (%)
Winter	+	3	2	5	
	*	3	2	5	
	**	0	3	3	
	***	0	1	1	
	Total	6	8	14	15
Spring	+	1	5	6	
	*	0	2	2	
	**	0	3	3	
	***	0	2	2	
	Total	1	12	13	14
Summer	+	0	5	5	
	*	0	2	2	
	**	0	2	2	
	***	0	5	5	
	Total	0	14	14	15
Autumn	+	12	1	13	
	*	4	2	6	
	**	1	0	1	
	***	3	0	3	
	Total	20	3	23	24

Analyzing seasonal discharge trends by river basins it is evident that except in summer, when there are no significant increase anywhere, in all seasons discharge increases in the Južna Morava basin, more precisely on the Toplica River. A significant increase was recorded during winter in the basins of Mlava, Pek and Ibar rivers, and at one station in the Timok basin, while in autumn the increase was recorded at the majority of stations in Zapadna Morava basin, then in Kolubara, Južna Morava, Danube and at one station in the basins of Velika Morava and Timok. A significant increase in discharge was never recorded at stations in the Drina and the Aegean basin (figures 4, 5 and 6).

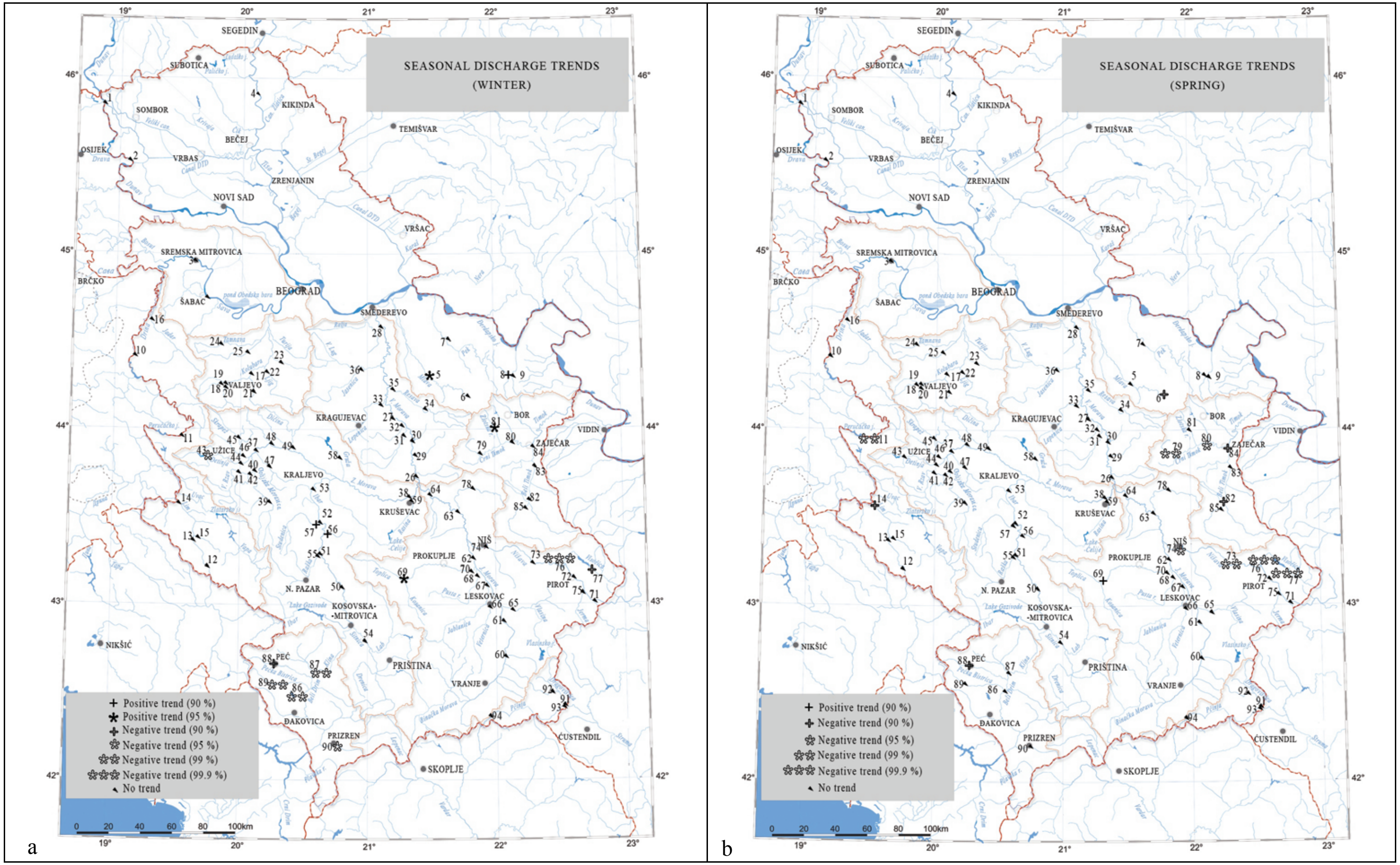


Figure 4. Spatial distribution of significant seasonal discharge trends in Serbia (a) winter, (b) spring

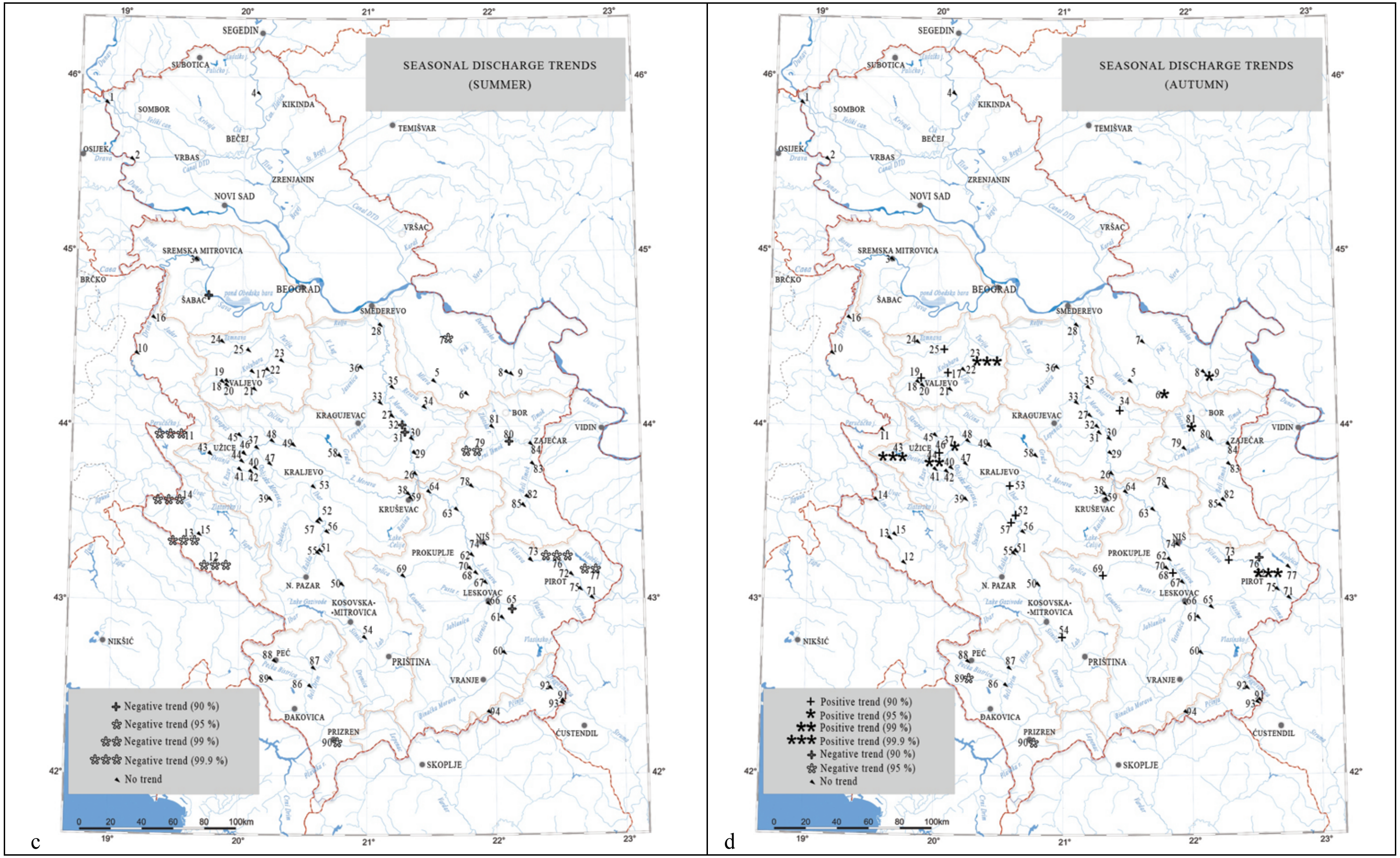
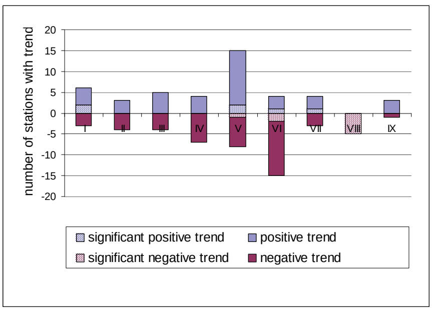


Figure 5. Spatial distribution of significant seasonal discharge trends in Serbia (a) summer, (b) autumn

Significant decrease of discharges in all seasons was recorded in the Južna Morava and Beli Drim basin. These are also the basins where in the autumn discharges decrease, while in other basins they increase. The largest decreases were recorded in summer mainly in Drina, then in Južna Morava, Danube and Sava, Velika Morava, Timok and in the Beli Drim basin at the station Prizren. Prizren is the station at which significant decrease was recorded in all seasons except spring. In the spring a significant decrease occurs in the basins of Timok, Drina and Mlava rivers. The distribution in summer is similar, except that the number of stations with decreasing discharges on above mentioned basins increases and expands to Velika Morava basin. Station where in all seasons, except for autumn, discharges decrease is Staničenje on the Temska River (Nišava basin, Južna Morava), and Visočka Ržana on the Visočica River, a tributary of the Temska River. Rivers in the basins of Kolubara, Zapadna Morava (except station Stapari on the Đetinja River) and the Aegean basin do not have significant decreases of discharges in any season, and stations in the Aegean basin do not have significant discharges trends at all.



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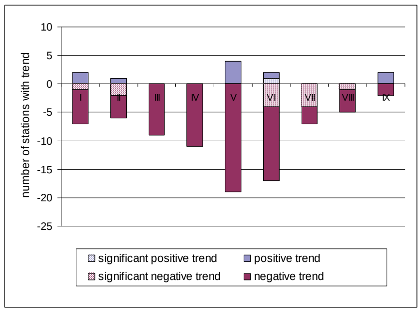
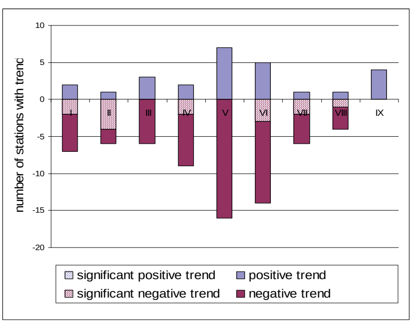
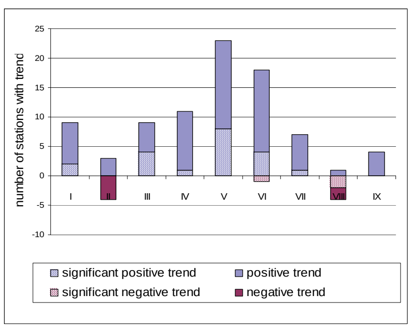


spring



summer



autumn

Figure 6. Seasonal disharge trends in Serbia by river basins
I – Danube, Sava and Tisa without major tributaries, II – Drina, III – Kolubara, IV – Velika Morava
V – Zapadna Morava, VI – Južna Morava, VII – Timok, VIII –Beli Drim, IX – Aegean basin

As on annual level, level of significance of seasonal trends should be interpreted in accordance with the quality of the data, i.e. first of all with the length of data series. Very significant increase happens only in autumn at stations Zeoke on the Peštan, Stapari on the Đetinja and Pirot on the Nišava River. Significant increase in autumn at Šengolj on the Đetinja River, and moderate significant increase in autumn on the Crnajka River and in the autumn and spring at Zlot on the Zlotska River and on the Mlava River should be taken with caution due to the insufficient length of time series. For the same reason, we can say that a moderate significant increase in autumn has only station Kratovska stena on the Zapadna Morava River.

There are no stations with very significant and significant decreases of discharges in autumn, while Staničenje appears as a station with very significant trend in three other seasons, then Visočka Ržana in the spring and Bajina Bašta, Brodarevo and Priboj in the summer. A significant decrease has Bogovina in the Timok basin in spring and summer, Bajina Bašta on the Drina and Bela Palanka on the Nišava in spring and Visočka Ržana in summer. Decrease of discharges on Temštica, Lim and Drina rivers as already mentioned is consequence of their altered natural regime. In winter, a significant decrease occurs in the basins of the Beli Drim, but the degree of confidence in this basin is limited by the reliability of data. Same should be applied when it comes to trends of moderate significance at these stations during winter, summer and autumn. Decrease of moderate significance occurs in winter at Stapari, in spring at Niš on the Nišava, Gamzigrad on the Crni Timok and in summer at Kučevo on the Pek River.

Conclusion

Rational water resources and natural disaster risk management, which is to be done with proactive approach, includes the studies and analyses related to all risk components including water resources (Hazard component). Analysis of mean annual and seasonal discharges on 94 hydrostations in Serbia, presented in this paper, has shown: that changes in water resources are present, but those statisticaly significant refer only to few river basins or stations; that seasonal changes in spring and summer reflect on annual changes; that they are mainly negative in that seasons; that in some cases are consequenses of antrophogenic factors, and in some others are results of low level of data confidence and require additional analysis.

There were no statistically significant discharge trends at 73% of analysed stations on annual and 76–86% on seasonal level. Significant annual discharge trends are negative at 24 stations, and only at one station – Pepeljevac on the

Toplica River – trend is positive. In most cases changes are negative with moderate and low significance. They are primarly related to rivers in Južna Morava, then Drina, Timok and Beli Drim basins. As the trends were calculated regardless of their causes, they must be interpreted cautiously, especially those obtained from insufficient length of time series (mainly stations in Adriatic basin). Significant and very significant decreases of discharges are registered on rivers where water reservoirs were built for water usage and riverbed regulations. Subsequently, this means that besides main purpose of reservoir, downstream discharges should be ensured.

Significant positive trends occur in autumn and on some rivers in winter, while in winter, spring and summer are mostly negative. Significant increasing discharge trends appear in autumn and winter mostly in Zapadna and Južna Morava and Kolubara basins. Increasing discharges at Pepeljevac on the Toplica River (Južna Morava) are constant on both seasonal and annual level. Except this station there are no increasing trends in spring, which can be explained by decreasing precipitation in South Europe in spring and shift of snow melting from spring to winter (Stahl et al, 2010). Significant decrease of discharge, as on annual level, occur primarily at the same stations on rivers in Južna Morava, Beli Drim, then Drina and Timok basins, meaning seasonal changes impact annual discharges and could be explained in the same way.

Areas where activities should primarily be focused in order to establish sustainable water resources management are:

- Basins of Toplica, Nišava, Pusta, Ibar and Kolubara rivers as areas on which the largest consequences related to the increase of discharges are possible.
- Basins of Južna Morava, Drina and Beli Drim rivers which are characterized by decreased discharges as a consequence of artificial regimes, within water management activities. Also, we should pay attention to interpretation of trends in Beli Drim basin because of low confidence of input data. Results indicate that water management ativities should be directed to Timok basin because of decreased disharges.

Further research should be focused on extreme discharge trends – their magnitude and frequency, because they are related to the most rivers in Serbia. Ristić et al (2012) remind that almost all basins south of Sava and Danube are torrential. Therefore more detailed analyses of hazard component, but also the population and their goods in hazard prone areas, presented in paper of Kovačević-Majkić, Panić, Miljanović & Miletić (2014) are prerequisite for adequate management of natural (river basins) and administrative (municipalities, districts) units, and for determination of those which have priority.

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