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SPATIAL DISTRIBUTION OF SPECIFIC RUNOFF IN SERBIA BASED ON RAINFALL-RUNOFF RELATIONSHIP

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Abstract: One of the indicators of water potential and water resources is specific runoff. Specific runoff for the whole territory of Serbia was obtained using the exponential relation between depth of runoff *Y* (mm) and precipitation *P* (mm). This relation is obtained on the basis of the mean annual amount of precipitation and annual water discharge, namely the depth of the runoff for 69 basins for the period 1961–2010. Coefficient of determination (R^2) of relation between the depth of runoff and precipitation is 0.72. The differences between measured and modeled values of specific runoff vary from basin to basin, but at the level of the whole Serbia it is 3.5%. More precisely, the measured specific runoff amounts 5.6 l/s/km^2, and the modeled specific runoff is 5.7 l/s/km^2. The verification was done by applying the model to 11 large river basins in Serbia. Spatial distribution of the modeled specific runoff is presented by a digital map of specific runoff with pixel resolution 100 × 100 m which enables the estimation of mean annual water discharge in any ungauged basin in Serbia.

Keywords: rainfall-runoff relation; specific runoff; spatial distribution; Serbia

Introduction

The issue of water potential and water resources is always topical. The increasing number of population causes an increase of their needs, which usually leads to higher water demand. On the other side, climate changes which have influence on water balance cause changes in spatial and temporal distribution of water resources. The main and the most usually used hydrological indicators of water potential and water resources is annual runoff, in most cases presented as the mean annual discharge or specific runoff.

In Serbia there were many studies about water quantity and water availability. Using the data for the period 1961–2010, Urošev et al. (2017) have calculated that in Serbia there are 5565 m^3/s of water. The ratio between international and national amounts of water is pretty unequal. The largest amounts of water have been recorded in the large international rivers: the Danube, the Sava, the Tisza, the Drina, the Lim, the Begej, and the Tamiš. Mean annual national water discharge varies for

*Corresponding author, e-mail: m.urosev@gi.sanu.ac.rs different observation periods: 596 m^3/s for the period 1951–1985 (Ocokoljić, 1993/94), 529 m^3/s for the period 1946–1978 (Vujnović, 1995), 509 m^3/s for the period 1946–1991 (Prohaska, 2003), 481 m^3/s for the period 1961–2010 (Urošev et al., 2017). After updating the data for the period 1961–2010, which was also used in this paper, national water discharge was 491 m^3/s which means that only 8.8% of the total water comes from the territory of Serbia. Temporal distribution and the trends of average discharges in Serbia for the same period 1961–2010 show that there are no significant trends on the majority of hydrological stations (Kovačević-Majkić & Urošev, 2014).

Besides discharge, specific runoff is one of the main indicators of water potentials. Many factors influence the amounts of specific runoff and hydrological regime of water bodies, as well the hydrological network and its density. These phenomena were the object of research activities of many authors (Arnell, 2014; Dukić, 1978; Dukić & Gavrilović, 2006; Jevdjević, 1956; Jones, 2013; Živković, 1995, 2009). Precipitation and evaporation as components of water balance have the highest influence on specific runoff. Geological, pedological, geomorphological, morpho-metrical, biological, as well as anthropogenic factors can have significant importance in some cases. Their differences cause spatial variability of specific runoff. Mean runoff coefficients are most strongly correlated to the indicators representing climate such as mean annual precipitation and the long-term ratio of actual evaporation to precipitation through affecting long-term soil moisture. This can be seen on global (McMahon, Peel, Pegram, & Smith, 2011), continental (Karamage et al., 2018), and country scales (Merz & Blöschl, 2009; Ri, Jiang, Sivakumar, & Pang, 2019). Land use, soil types, and geology do not seem to exert a major control on runoff coefficients on these spatial scales.

Based on the main water balance components for twenty regions in Serbia and also from the neighboring basins data, Isailović, Prohaska, and Majkić (2007) defined the relationship between the average values of runoff and precipitation. They have concluded that the linear model they used is simple but reliable for the territory of Serbia and that the greater attention should be given in the areas with higher altitude because of the factor of the lower air temperature. In recent years there have been numbers of papers on the estimation of the mean flows in Serbia using gridded precipitation and temperature data (Blagojević, Plavšić, Ćatović, & Todorović, 2018; Prohaska, Plavšić, Prohaska, & Todorović, 2019). Prohaska et al. (2019) estimated the mean annual flow within the territory of Serbia using the Langbein's method with calibrated parameter Θ, which was mapped in order to facilitate the estimation of the mean flows in small ungauged basins. The results showed that additional care should be taken in karst basins. In order to present spatial distribution of specific runoff, Urošev et al. (2017) used the relationship between precipitation and depth of runoff given by Isailović et al. (2007), but modifying it in accordance with precipitation data given by Štrbac (2014).

In this paper we have analyzed the spatial distribution of the specific runoff in Serbia based on the data from 93 hydrological stations for the period 1961–2010. In order to obtain the specific runoff for the entire territory of Serbia we have created a model (relationship) between precipitation and runoff. The aim of this research is to try to find a model that describes the spatial distribution of specific runoff as an indicator of water resources.

Data and methodology

To calculate the specific runoff, we have used data from 93 hydrological stations which have at least 30 years period of discharge measurement in the period 1961–2010. The source of data was the Republic Hydrometeorological Service of Serbia (RHMSS), or, to be more specific, hydrological yearbooks of the Federal Hydrometeorological Service of Yugoslavia (FHSY) for the period 1961–1990 (FHSY, 1961–1990), and hydrological yearbooks of RHMSS for the period 1991–2010 (RHMSS, 1991–2010). The data sets used in this research refer to the period 1961–2010. Exception were the stations which started to work in 1981 and stations in the Beli Drim River basin, because the available data cover the period till 1995. The 50-year period of 1961–2010 is chosen as optimal for all the stations in Serbia, because around year 1960 water discharge data from the majority of stations (besides few stations on large rivers) became available in hydrological yearbooks. Also the number of 93 investigated stations is optimal for this period, as we practically included almost all the stations that have at least 30 years of data, i.e. which started with discharge measurement before year 1981. The period 1961–2010 is representative because it is sufficiently long to include cyclical changes of climate and includes both water-abundant and dry periods. Also, the mean square errors of mean multiannual discharge E_{Qo} were less than 5–10% of mean multiannual discharge Q_0 for all the 93 investigated stations, which means that the length of time series is sufficient to determine Q_0. We are now in the process of adding the data for the current decade (2011–2020) to our database and luckily at the end of year 2021 after the data check we will be able to update the database and all the results from it, including the ones presented in this paper.

The obtained values of specific runoff that we have named *measured specific runoff* (*q*) are presented in Table 1 and they represent the specific runoff which is formed on the territory of Serbia and on the immediate (direct) basins. That means that the data on the drainage areas for the international rivers such as the Danube, the Sava, the Tisza, the Lim etc. are just for the area within the territory of Serbia and for the rivers in Serbia the data on the drainage area are provided for immediate sub-basin, i.e. from upstream station to the investigated station. Consequently, the specific runoffs were calculated using such data about the area. The data on discharge are calculated as the difference of discharge measured at upstream and downstream hydrological station, and for the international rivers as the difference of the discharge at the first hydrological station in Serbia and at the cross-section at the entrance of the rivers in Serbia. The estimated data on discharge on the entrance of the rivers in Serbia are given in the document "Serbia water master plan" (Jovičić et al., 2001).

To the mentioned 93 basins we have also added four more basins: the direct basin of the Danube, the direct basin of the Beli Drim and two small basins belonging to the Aegean basin. Also we have divided the Jerma River basin into two basins because the Jerma springs in Serbia, then leaves the territory of Serbia and again flows back in Serbia. That is why we have treated these two parts of the Jerma River basin separately. Overall, the entire territory of Serbia is divided in 98 direct basins. In order to obtain realistic data on specific runoff, we have excluded those basins with anthropogenic influence (mostly the rivers with large reservoirs and water transfers from other basins) as well as those basins with dominant karst areas (the difference between surface and real basin area). Eventually, we used data from 69 basins to estimate and present the specific runoff in Serbia.

The spatial distribution of precipitation in Serbia was calculated on the basis of the relationship between the precipitation from 426 pluviometric stations and their altitude (Štrbac, 2014). The resolution of precipitation and DTM was 100 × 100 m. These data, previously prepared by Štrbac (2014), were used for the calculation of the mean annual precipitation for the above mentioned 69 basins and for the determination of the relationship between precipitation and depth of the runoff for those basins (Figure 1).

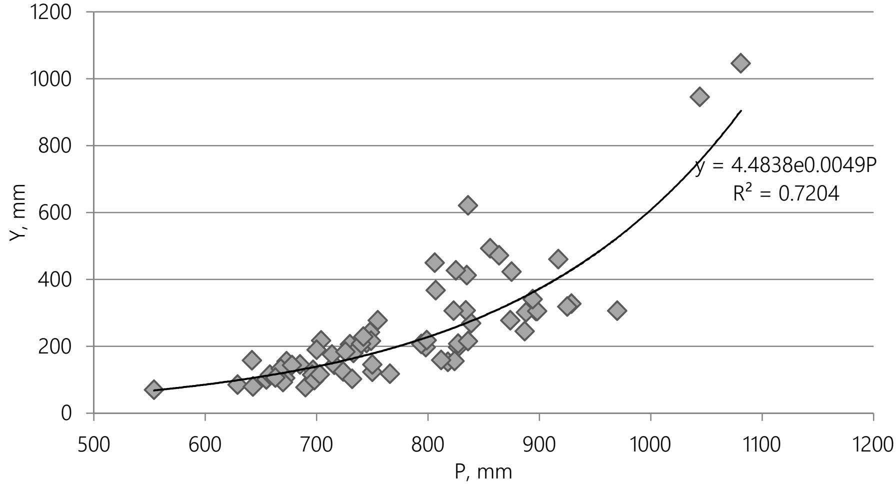

Figure 1. Relationship between precipitation P (mm) and depth of runoff Y (mm) for the territory of Serbia.

This relationship is presented by Equation 1:

$$Y = 4.4838e^{0.0049P} \quad (1)$$

where *Y* is depth of runoff in [mm] as dependent variable, and *P* is precipitation in [mm] as independent variable. Coefficient of determination of this relationship (R^2) is 0.72, and the correlation coefficient (*r*) is 0.85, which indicates that there is very strong positive relationship, bearing in mind that the relationship is based on a large data set (69 basins). This value can be compared with the result presented in the paper by Merz and Blöschl (2009), where they obtained correlation coefficient (*r*) of 0.71 between runoff and mean annual precipitation for the entire territory of Austria (459 catchments). They also concluded that the values of runoff coefficients mostly depend of mean annual precipitation and soil moisture. Equation 1 was applied to the precipitation raster layer and then divided by 31.536 in order to calculate the specific runoff:

$$q'=Y/31.536 \quad (2)$$

where *Y* is depth of runoff in [mm], and *q'* is modeled specific runoff in [l/s/km^2].

That is how we have calculated specific runoff, which we have named *modeled specific runoff* (*q'*), for each pixel with dimensions 100 × 100 m. On the basis of that data we were able to develop a map of the spatial distribution of specific runoff which is presented in Figure 2.

In order to verify the obtained results, we have calculated the average modeled specific runoff for all the basins and compared them with the measured values (Figure 3). The distribution of differences (errors) is given in Figure 4. Another verification of the obtained results was done by calculating the specific runoff for 11 large basins (the direct basin of the Danube, the Tisza, the direct basin of the Sava, the Drina, the Kolubara, the Velika Morava, the Zapadna Morava, the Južna Morava, the Timok, the Adriatic Sea basin (the Beli Drim River), and the Aegean Sea basin (the Lepenac, the Dragovištica and the Pčinja)). For the calculations, modeling process, analyses, and mapping of the results we have used the following software: *MS Excel* and *QGIS (3.12)*.

Results and discussion

Table 1 provides both measured and modeled specific runoff data from hydrological stations in Serbia but calculated as it is explained in the methodology section. That is why we have got an impossible negative value of specific runoff (–0.07 l/s/km^2) for the Velika Morava basin at Varvarin hydrological station. Namely, that basin is pretty small, so the sum of water discharges from the upper basins: the Zapadna Morava basin at Jasika, the Rasina basin at Bivolje, and the Južna Morava basin at Mojsinje, is bigger than the one measured for the Velika Morava basin at Varvarin. It would be better to state that the value of the specific runoff for this basin is zero. In Table 1, the data for 96 basins are presented (two small basins belonging to the Aegean basin had no discharge data). Fifteen of them have been excluded because of the anthropogenic influence on the runoff. We have also selected twelve basins with significant participation of karst, and subsequently significant influence on the runoff. Therefore, we have used 69 basins for the specific runoff modeling.

Previous results show that the average specific runoff in Serbia is low. Ocokoljić (1993/94) has calculated that the average specific runoff in Serbia is 6.7 l/s/km^2 and according to Manojlović and Živković (1997) it is 7.1 l/s/km^2, 5.8 l/s/km^2 according to Prohaska (2003) and 5.4 l/s/km^2 according to Urošev et al (2017). Another result that is worth mentioning is the Danube River Basin Management Plan (Institut za vodoprivredu „Jaroslav Černi“, 2014) where one of the newest maps of the specific runoff for the Danube basin in Serbia (92.6% of the entire territory of Serbia) is provided with the estimated runoff of 5.4 l/s/km^2. In this paper we have calculated that the average observed specific runoff in Serbia for the period 1961–2010 is 5.6 l/s/km^2.

Table 1
Measured (q) and modeled (q') specific runoff in Serbia for the period 1961–2010

No	River	Hydrological station	F (km^2)	*q* (l/s/km^2)	*q'* (l/s/km^2)	N/A	Karst
		DANUBE, SAVA, TISZA					
1	Danube	Bezdan	37	2.7	3.1	N	/
2	Sava	Sremska Mitrovica	1267	2.5	4.3	N	/
3	Tisza	Senta	946	2.2	2.2	N	/
4	Mlava	Žagubica*	139	12.8	5.8	N	+
5	Mlava	Gornjak*	566	8.7	6.5	N	+
6	Pek	Kučevo	838	8.8	6.8	N	+
7	Šaška	Crnajka*	248	5.8	7.6	N	+
8	Crnajka	Crnajka*	78	7.1	5.4	N	+
9	Danube	Direct basin	30682	2.5	3.5	N	/
		DRINA					
10	Drina	Bajina Bašta	2660	11.7	11.5	A	/
11	Drina	Radalj*	982	8.1	15.2	A	/
12	Lim	Brodarevo	218	15.6	9.8	N	/
13	Lim	Prijepolje	399	15.0	10.2	N	/
14	Lim	Priboj	339	6.5	13.2	A	/
15	Mileševka	Prijepolje*	151	8.8	10.4	N	/
16	Jadar	Lešnica*	1012	7.8	11.5	N	/
		KOLUBARA					
17	Kolubara	Slovac	392	6.2	8.3	N	/
18	Jablanica	Sedlare	144	9.7	16.8	N	/
19	Obnica	Belo Polje	184	9.7	11.8	N	/
20	Gradac	Degurić	158	17.3	13.5	N	+

Table 1
Continued

No	River	Hydrological station	F (km^2)	q (l/s/km^2)	q' (l/s/km^2)	N/A	Karst
		KOLUBARA					
21	Ribnica	Paštrić	114	10.4	13.6	N	/
22	Ljig	Bogovađa	657	6.6	8.4	N	/
23	Peštan	Zeoke	121	5.0	6.8	A	/
24	Tamnava	Koceljeva	202	4.9	7.9	N	/
25	Ub	Ub	219	6.2	7.3	N	/
		VELIKA MORAVA					
26	V. Morava	Varvarin	313	-0.1	3.4	A	/
27	V. Morava	Bagrdan	1047	4.9	3.9	N	/
28	V. Morava	Ljubičevski most	2068	3.2	3.6	N	/
29	Crnica	Paraćin	296	11.8	5.4	N	+
30	Ravanica	Ćuprija	148	4.6	4.8	N	/
31	Lugomir	Majur	432	4.1	4.4	N	/
32	Belica	Jagodina	186	3.3	3.9	N	/
33	Lepenica	Batočina	586	3.4	4.5	N	/
34	Resava	Manastir Manasija	422	8.8	6.0	N	+
35	Resava	Svilajnac	331	3.6	4.5	N	/
36	Jasenica	Smederevska Palanka	468	3.9	6.1	N	/
		ZAPADNA MORAVA					
37	Z. Morava	Kratovska stena	313	5.0	8.1	N	/
38	Z. Morava	Jasika	2460	3.7	6.5	N	/
39	G. Moravica	Ivanjica	479	14.6	13.0	N	/
40	G. Moravica	Arilje	361	10.1	13.6	N	/
41	V. Rzav	Roge	433	14.0	16.9	N	+
42	V. Rzav	Arilje	144	13.0	16.0	N	+
43	Đetinja	Stapari	326	11.1	12.6	A	+
44	Đetinja	Šengolj*	175	10.8	11.4	N	/
45	Skrapež	Kosjerić*	158	9.6	11.3	N	/
46	Skrapež	Požega	467	6.8	8.7	N	/
47	Bjelica	Guča*	240	9.7	11.8	N	/
48	Kamenica	Prijevor*	198	9.7	8.8	N	/
49	Čemernica	Preljina	602	6.6	7.3	N	/
50	Ibar	Leposavić	1694	5.6	5.1	N	/
51	Ibar	Raška	411	5.0	8.1	N	/
52	Ibar	Ušće	359	5.8	5.4	N	/
53	Ibar	Lopatnica lakat	400	9.7	8.8	N	/
54	Sitnica	Nedakovac	2594	4.6	4.2	N	/
55	Raška	Raška	1040	6.9	4.7	N	/
56	Jošanica	Biljanovac	255	13.4	10.7	N	/
57	Studenica	Ušće	532	13.1	8.9	N	/
58	Gruža	Guberevac	491	2.4	6.9	A	/
59	Rasina	Bivolje	968	7.7	6.8	A	/

Table 1
Continued

No	River	Hydrological station	F (km^2)	q (l/s/km^2)	q' (l/s/km^2)	N/A	Karst
		JUŽNA MORAVA					
60	J. Morava	Vladičin Han	3011	4.2	5.0	A	/
61	J. Morava	Grdelica	665	8.5	9.1	N	/
62	J. Morava	Korvingrad	745	3.1	4.7	N	/
63	J. Morava	Aleksinac	1020	3.6	3.7	N	/
64	J. Morava	Mojsinje	712	4.2	3.9	N	/
65	Vlasina	Vlasotince	982	10.0	8.2	A	/
66	Veternica	Leskovac	500	7.8	8.5	A	/
67	Jablanica	Pečenjevce	898	4.6	6.0	N	/
68	Pusta reka	Pukovac	560	2.9	3.6	A	/
69	Toplica	Pepeljevac	976	6.5	5.8	N	/
70	Toplica	Doljevac	1085	3.0	4.1	N	/
71	Nišava	Dimitrovgrad	84	3.4	3.8	N	/
72	Nišava	Pirot	370	5.8	3.7	A	/
73	Nišava	Bela Palanka	463	5.0	3.4	N	/
74	Nišava	Niš	877	6.6	5.9	N	/
75	Jerma	Sukovo	267	5.7	5.4	N	/
76	Jerma	Strezimirovci	111	6.9	7.5	N	/
77	Temštica	Staničenje	414	13.1	6.4	A	/
78	Visočica	Visočka Ržana	297	14.3	7.7	N	/
79	Sokobanjska Moravica	Žučkovac*	590	4.0	5.1	N	/
		TIMOK					
80	Crni Timok	Bogovina	433	13.3	6.8	N	+
81	Crni Timok	Gamzigrad	493	6.0	4.5	N	/
82	Zlotska reka	Zlot*	208	13.4	5.8	N	+
83	Beli Timok	Knjaževac	683	7.7	5.9	N	/
84	Beli Timok	Vratarnica	500	3.7	4.8	N	/
85	Beli Timok	Zaječar	408	4.6	4.0	N	/
86	Svrljiški Timok	Rgošte*	397	6.9	5.8	N	/
		ADRIATIC BASIN					
87	Beli Drim	Kpuz	1357	11.7	7.8	N	/
88	Klina	Klina	428	3.3	5.2	N	/
89	Pećka Bistrica	Peć-Klisura	193	30.0	24.5	N	/
90	Dečanska Bistrica	Dečani	117	33.2	29.3	N	/
91	Prizrenska Bistrica	Prizren*	166	19.7	8.8	N	/
92	Beli Drim	Direct basin	3070	13.5	8.7	N	/
		AEGEAN BASIN					
93	Dragovištica	Ribarce*	333	9.1	5.9	A	/
94	Ljubatska	Bosilegrad*	197	6.6	5.6	N	/
95	Brankovačka reka	Ribarce*	163	7.3	5.6	N	/
96	Pčinja	Barbace	382	8.8	6.4	N	/

Note. *1981–2010; F = basin area; q = measured runoff; q' = modeled runoff; N = natural; A = anthropogenic; + = significant participation of karst; / = no significant participation of karst.

According to data given by Food and Agriculture Organization of the United Nations (2003), in comparison with the neighboring countries, Serbia has a favorable position in relation to Hungary (2.0 l/s/km^2), and approximately the same as Bulgaria (6.0 l/s/km^2), Romania (5.6 l/s/km^2), North Macedonia (6.7 l/s/km^2). In relation to Croatia (21.1 l/s/km^2), Bosnia and Herzegovina (22.0 l/s/km^2) and Albania (29.7 l/s/km^2) Serbia has a lower value of specific runoff. The country which has the largest extent of water resources in the region is Montenegro with the specific runoff of 44 l/s/km^2 (Vlada Crne Gore, Ministarstvo poljoprivrede i ruralnog razvoja, 2017).

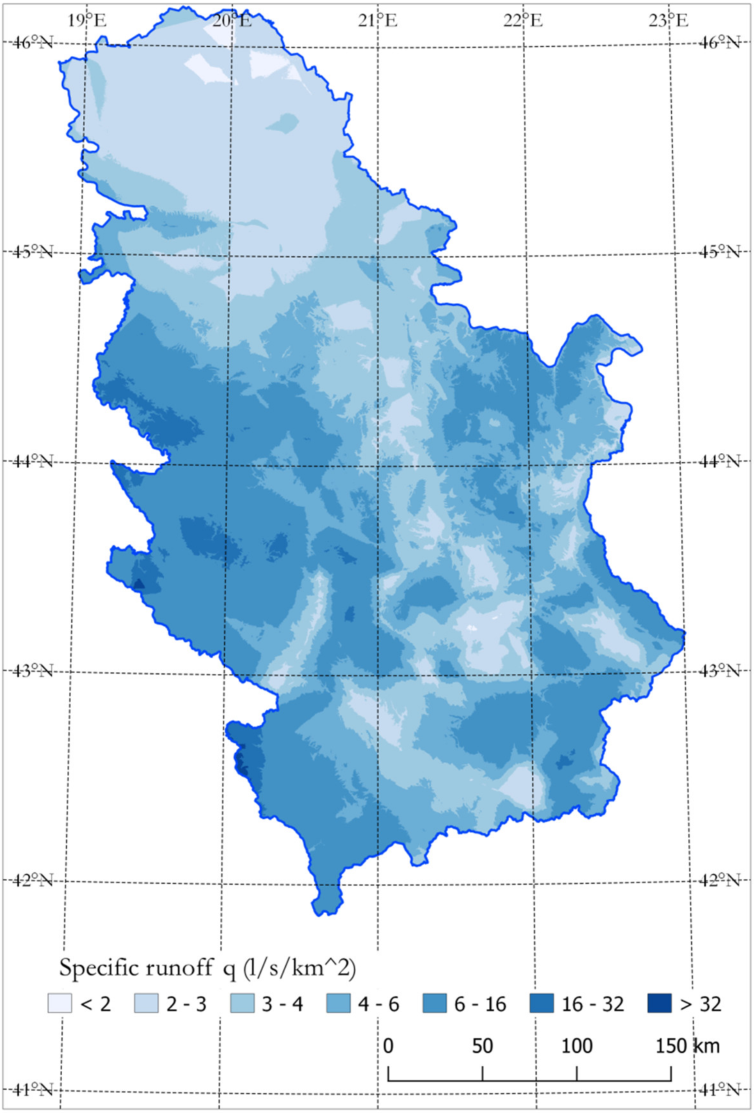

Figure 2. Spatial distribution of the specific runoff in Serbia in period 1961–2010.

Spatially, the values of the specific runoff vary from less than 1 l/s/km^2 to 40 l/s/km^2 (Figure 2). It is confirmed that specific runoff increases with altitude. Areas with high values of specific runoff are the areas of the Prokletije Mts. and Šar planina Mt. (upper parts of the Beli Drim and its tributaries), followed by the upper parts of the Drina and its tributaries' basins, and parts of spring areas in the Zapadna Morava basin. The lowest specific runoff is in the lowland parts of Serbia (parts of the Danube basin which directly drain to the Danube, lower parts of the Tisza, Velika Morava, Kolubara, Južna and Zapadna Morava, and Timok basins).

Ocokoljić (1993/94) claimed that the areas with the largest values of the specific runoff (the highest precipitation and the lowest evaporation) are those south from the Sava and the Danube, and more specifically, those areas with the altitude over 500 m. They encompass 39% of the territory of Serbia. Manojlović and Živković (1997) have got similar results. According to them, 35% of the specific runoff is generated in the areas between 400 and 700 m a.s.l. and these areas comprise 22% of the entire territory of Serbia.

Comparing measured and modeled values of the specific runoff (Table 1 and Figure 3), it is obvious that they vary from basin to basin. The largest differences (relative errors) are obtained in the basins with anthropogenic influence (reservoirs) such as the Gruža River basin at Guberevac (188%) and the Lim River basin at Priboj (102%). The minimal errors are on the direct basin of the Južna Morava at Aleksinac (2.5%) and the Ravanica River at Ćuprija (4.3%). These are extreme values, but the average error for all the 98 basins is 30%.

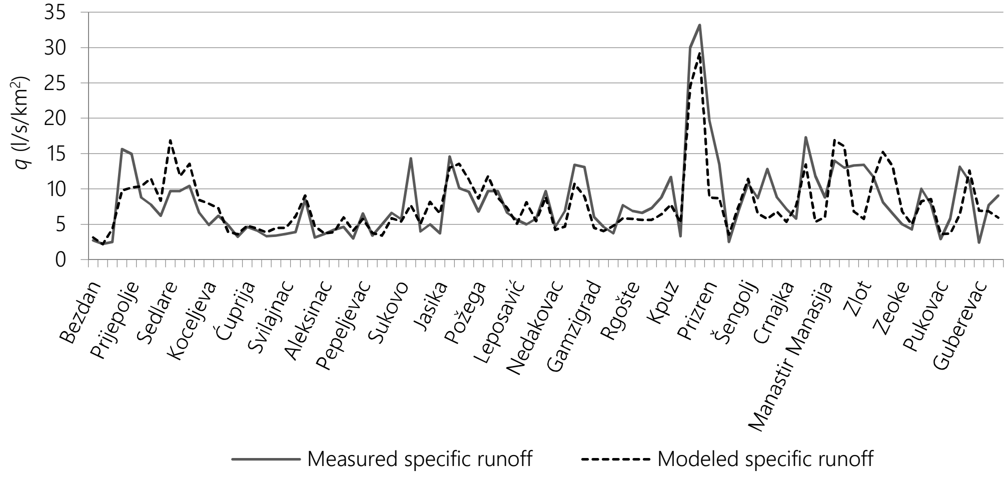

Figure 3. Comparison of measured and modeled specific runoff in Serbia in the period 1961–2010.

The distribution of the relative errors of the modeled specific runoff is presented on Figure 4. From this histogram we can conclude that the most frequent group of relative errors is between 10 and 20% (22 basins) and that 50% of all the investigated basins have errors below 25%, or that errors less than 50% are observed at 82% of the modeled basins (78 basins). However, it should be noted that the relationship between precipitation and runoff is established for the entire territory of Serbia, and not for specific regions or basins. As we have mentioned before, the average specific runoff in Serbia is 5.54 l/s/km^2 and the modeled specific runoff, calculated using equations 1 and 2, is 5.75 l/s/km^2, which means that the model error on the level of the entire Serbia is 3.5%.

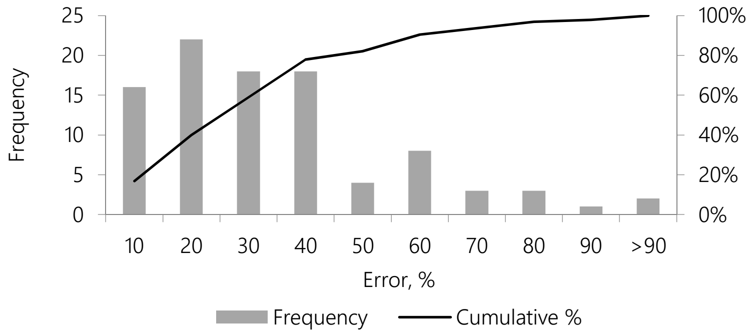

Figure 4. Distribution of relative errors of the modeled specific runoff in Serbia in the period 1961–2010.

When applied to the 11 larger river basins, the differences between measured and modeled specific runoff also vary from basin to basin (Table 2). The maximal relative error is in the Tisza basin (231.5%) and the minimal errors are in the Južna Morava (3.5%) and Velika Morava basins (6.2%). The average error for all the 11 river basins is 43%. However, if we look at the level of Serbia again, since one formula was used for all the 11 basins, we can conclude that the difference between the measured and the modeled specific runoff is 2.9%, which is practically the same as in the previous case with all the 98 basins.

Table 2
Measured (q) and modeled (q') specific runoff for 11 large river basins in Serbia

River basin	q (l/s/km^2)	q' (l/s/km^2)	Relative error, %
Direct Danube	4.3	3.9	9.2
Tisza	0.7	2.4	231.5
Sava	2.6	3.9	50.4
Drina	10.4	11.9	13.8
Kolubara	4.6	7.9	71.3
Velika Morava	4.0	4.2	6.2
Zapadna Morava	6.7	7.3	9.6
Južna Morava	5.6	5.4	3.5
Timok	6.0	4.9	17.2
Adriatic Sea basin	13.4	9.6	28.7
Aegean Sea basin	9.1	6.2	32.4
Serbia	5.6	5.8	2.9

The results presented in this paper can be applied, together with other methods, for a number of practical tasks in hydrology and water resource management. One of them is the estimation of the mean annual specific runoff, and then the mean annual water discharge in any ungauged basin in Serbia. The digital map of the specific runoff in Serbia, presented in Figure 2, provided as an active raster layer of the specific runoff with pixel resolution of 100 × 100 m enables to calculate the runoff for any area (basin) within the territory of Serbia with most of the available GIS software. We already shared this data (raster file) with the Republic Water Directorate of Ministry of Agriculture, Forestry and Water Management for their project *Water Management Plan on the territory of the Republic of Serbia for the period 2021-2027*.

The established relationship presented in Equation 1 can be used for preliminary assessment of the changes in the runoff due to the changes in rainfall caused by climate changes. The described model illustrates the general behavior of these changes, and the precise quantification of the impact of climate changes will be determined not only by the general change of annual precipitation, but also by a possible change of seasonal precipitation distribution and a change of temperature regime. However, these phenomena were not considered in this paper, so further research could focus on these issues.

Conclusion

In this paper we have presented the method for obtaining the specific runoff and its spatial distribution in Serbia. The general relations of the most important components of the hydrological balance—precipitation *P* and runoff, expressed through the depth of runoff *Y*, were analyzed. The analysis of the results led to the following conclusions:

- the relationship between rainfall and runoff can be approximated by an exponential equation;
- the derived relationship is very simple and can be used for general estimation of the runoff in ungauged basins, as well as for a rough preliminary assessment of changes in the runoff due to the changes in precipitation caused by climate changes;
- the relation that was developed on the data from 69 basins, applied on 98 direct basins and verified by 11 large basins has an error of 3% on the level of the entire Serbia.

The differences between measured and modeled values of the specific runoff on the basin level can be explained by the simplicity of the applied method (based just on precipitation as a runoff factor) and by the fact that precipitation data themselves were modeled, which means we have multiplication of errors. Possible improvement of the model can be found in the sphere of getting more accurate data on the basin level (local level) by incorporating new hydrometric data and various physical-geographical factors that have a significant impact on runoff.

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